PROGRAMME OF THE EUROPEAN UNION

COPERNICUS DATA SPACE ECOSYSTEM

ANNUAL REPORT 2023

DATASPACE.COPERNICUS.EU

FOREWORD

Having learned about the objectives of the Copernicus Program in 2010 – at that time still named GMES, I will never forget the first meeting I had with Volker Liebig, Director of Earth Observation and Gunther Kohlhammer, Head of Operations at ESRIN. I was immediately impressed by ESA's vision, the scientific background of the mission, and the new insights it would provide on our planet. However, the most fascinating element was ESA's open acknowledgement, that the 10-fold increase in data along with the new free and open data access policy would present a whole new challenge to its teams, sharing data and insights with a global community. From that moment on, I became Copernicus' most enthusiastic supporter and committed to contributing all that we could to the success of the Sentinel missions.

Over more than 10 years, the excellent collaboration with ESA and their experts gave us the chance to continuously improve data access. Initially optimizing data downloads for the Copernicus Open Data Hub at data rates never experienced before, the focus shifted more and more to the effective and sustainable use of the data, making the data available in public clouds (DIASes) for more analytics and insights. The DIAS initiative provided an opportunity for the ecosystem of service providers and experts to join forces and work together to create platforms driven also by the users' needs. It gave T-Systems and consortium members the chance to connect and work with the champions of the Earth Observation community and drive forward key innovations. Examples of this are Sinergise's groundbreaking Sentinel Hub, which was awarded the Copernicus Masters Prize under the patronage of Josef Aschbacher in 2015, VITO's development of openEO, the de facto standard of processing, and the unprecedented success of the CREODIAS platform powered by CloudFerro, innovating Earth Observation with large-scale and immediately available online data storage, high-speed data access, and an integrated cloud environment for on-demand analytics.

The experience ultimately resulted in establishing a unique European service team to address the new Copernicus Data Access requirements of ESA and the European Commission from December 2022. It is a privilege for the service team consisting of T-Systems, CloudFerro, Sinergise, VITO, ACRI-ST, DLR and Starion to introduce to you the first Annual Report of the new Copernicus Data Space Ecosystem (CDSE) covering the period July until December 2023.

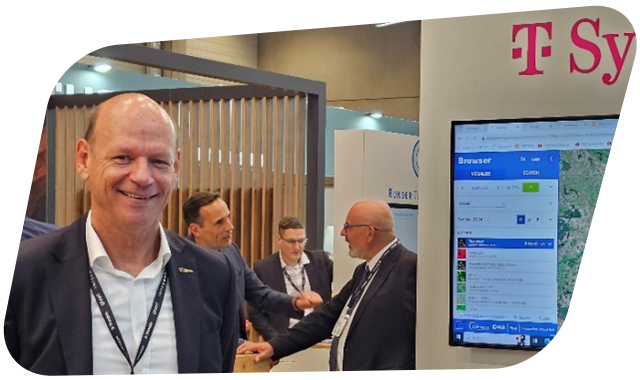
The report summarizes the new services, functions and data formats that have been made available. The stream- lined services provide immediate insights and make them available to a much wider audience beyond the remote sensing community. A range of APIs facilitates programing, automation of tasks, and the use of machine learning. Cloud-optimized data formats accelerate analytics. Moreover, the ability to immediately access the full mission data online enables new use cases, reduces data transfers, and fosters sustainability.

However, the proof of the pudding is in the eating, and we are delighted the user statistics in the report are confirming the usefulness of the innovations. Following a smooth transition for users of the legacy Data Hub Services in the last quarter of 2023, we continue to see a strong uptake of all new services and the trend is clearly shifting from data download towards the use of the Copernicus Browser and openEO streamlined services.

Moreover, we believe CDSE will also be very attractive for third parties to join the new Ecosystem. The effort to generate new services and data has been significantly lowered. Third parties will be able to benefit from the visibility in the growing community and can easily contract professional cloud computing and other supporting services to complement the free and open CDSE services.

We invite all interested parties to join us in the Ecosystem, to obtain new insights or create business on top of the data!

I would like to express my sincere gratitude to ESA and the European Commission for their visionary guidance over the years, and the very professional and trustful collabo- ration to advance the Copernicus program together. A very special thank you goes to all members of our extensive service team, spread across Europe. Thank you for the many hours we could spend together to overcome numerous challenges – including the Covid-19 pandemic – and to achieve what we have established, the beginning of a new era in the Copernicus program.



Jurry de la Mar
CDSE Implementation Manager and Copernicus fan

T-Systems International GmbH

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Title image: source: *copernicus.eu, Image of the Day, 2024/03/16 Camargue*

DOCUMENT OBJECTIVES

This document summarises the functioning of the Copernicus Data Space Ecosystem (CDSE) in 2023 in providing the Data Access Services for the Copernicus Sentinel Missions operated by ESA, providing an in-depth analysis of the publication and usage trends for the satellite data managed within the CDSE. It also presents the status of services currently in production and an outlook for the future.

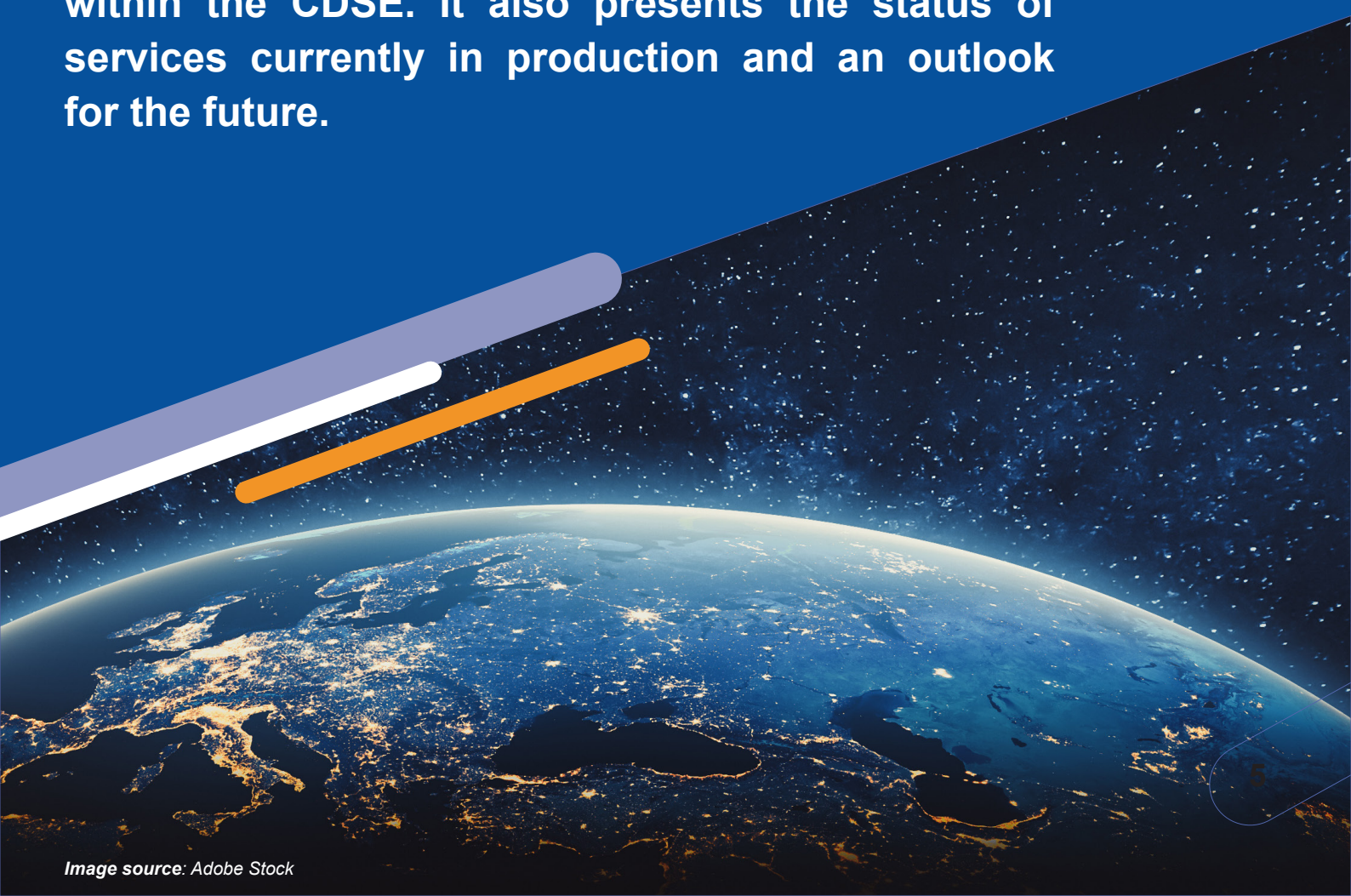


***Image source**: Adobe Stock*

EXECUTIVE SUMMARY

The Copernicus Data Space Ecosystem (CDSE) features an innovative approach to making use of satellite imagery. Huge amounts of Earth observation (EO) data, both current and historical, are immediately available for download and processing through multiple interfaces. The ecosystem makes interoperability easy thanks to open-source technology, thus CDSE's offering is ever-expanding. This approach builds a comprehensive environment for accessing and utilizing EO data, leading to a growing community of users employing the expanding capabilities. The service has maintained high availability, and customer support has been persistently well-rated. Plans for the future can be summarized as: more data, more services, and an even more user-friendly environment.

Why is CDSE a breakthrough?

With up to 30 TB of data produced daily, the Copernicus program is one of the biggest civilian data producers in the world. Tapping into this resource can be a major boost to the data-driven European economies. Streamlining this process is crucial, and this is exactly what CDSE does.
CDSE eliminates the technical complexity of accessing and processing data, allowing users to focus on applications.

- Rather than retrieving data from archives for hours or days at a time, CDSE offers immediate access to full spatial and temporal coverage of Copernicus data.
- CDSE is more than just an efficient data download service. Users do not need to be equipped with advanced tools and powerful computers for processing raw data; they can utilize easy-to-use interfaces and scalable processing services to derive value from the data.

Key numbers

Please note the figures below for a quantitative rundown of CDSE in 2023 (data as of 31.12.2023).
For up-to-date statistics visit:
https://dashboard.dataspace.copernicus.eu/

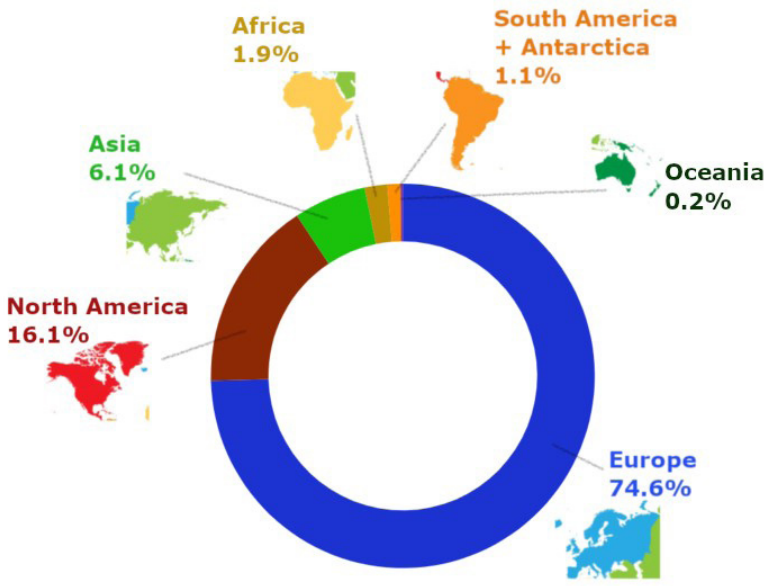
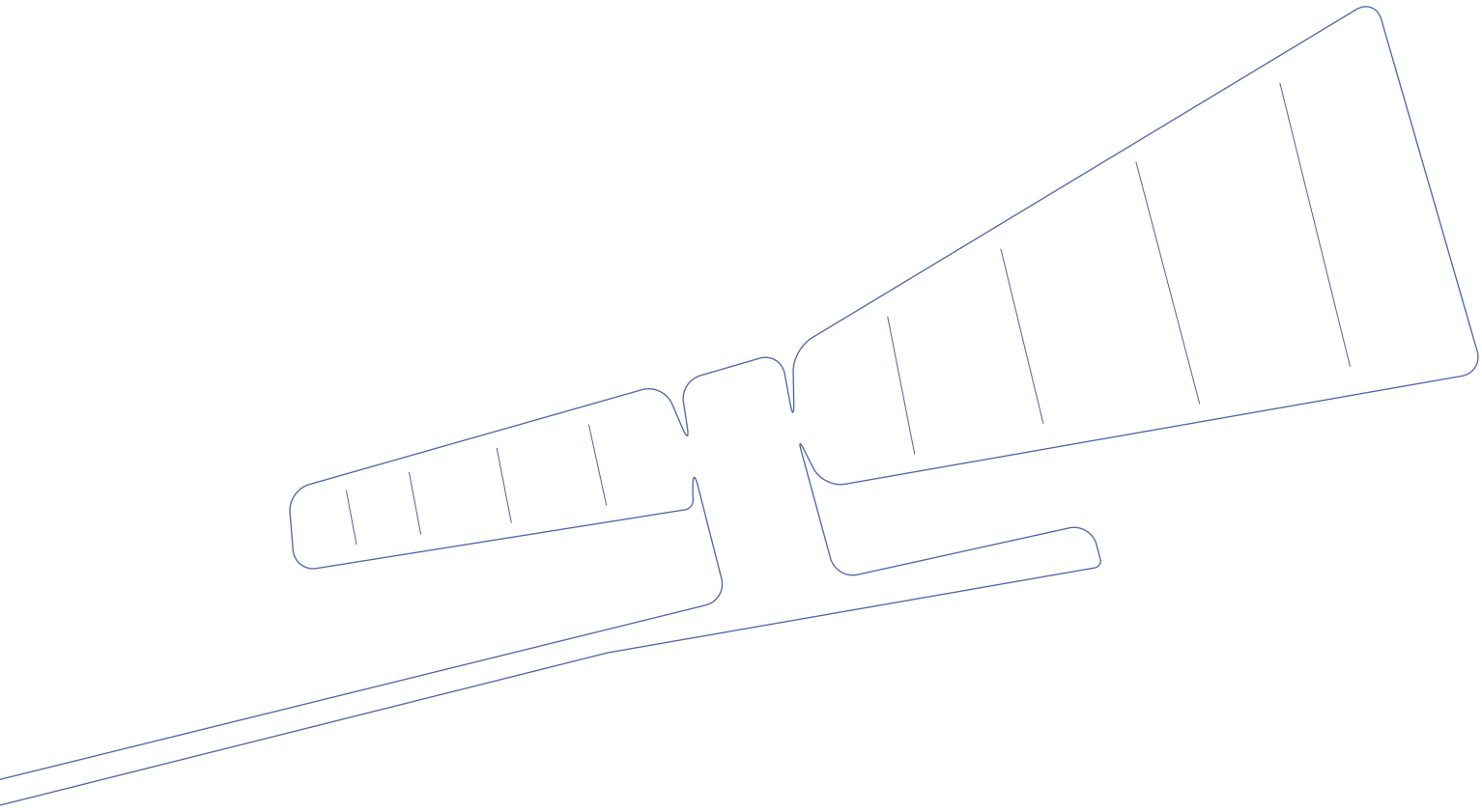


FIGURE 1: Percentage split of downloads by volume per continent in 2023 (since July).

- More than **68 PB of online data** – starting with 40 PB at the service kick-off and approaching 75 PB at the end of 2024 Q1.
- More than **100 million individual Sentinel products** in online storage, with up to 1000 catalogue queries per second (2 billion queries monthly).
- Over 30 PB delivered by the EO repository to the cloud environment only in December 2023, with almost 6 PB of direct downloads to users, 15 PB to users in federated clouds, 10 PB to streamlined data access interfaces, and the rest for technical goals related to tasks such as: traceability, mosaic generation, reprocessing and others.
- **84.000 users** registered in 2023.
- 74.6% of all data downloads were completed within Europe.
- Up to **90 MB/s** average download speed.
- Almost **150 million requests** processed by Sentinel Hub services in 2023, translating to over 450 million processing units (PU) consumed for streamlining access to Sentinel data. With one PU corresponding to approximately 26 km² of Sentinel-2 data processed at full resolution, the total represents almost 12 billion km² or **80 times the area of Earth landmass**. More than 100 trillion pixels of data were processed along the way.
- Over 7.3 million requests processed through the openEO, with a steady increase in the number of users.



1 INTRODUCTION

Copernicus is the Earth observation component of the European Union's Space programme. It provides accurate, timely and easily accessible information to improve the management of the environment, understand and mitigate the effects of climate change and ensure civil security. ESA has developed a new family of satellites, called Sentinels, specifically for the operational needs of Copernicus. At present, two complete two-satellite constellations, Sentinel-2 and Sentinel-3, are in orbit plus two additional single satellites, Sentinel-5P and Sentinel-6 Michael Freilich. With the end of the mission for the Sentinel-1B satellite, Sentinel-1C is planned to join Sentinel-1A in orbit as soon as possible to restore the Sentinel-1 constellation.

The constellation consists of several satellite types with multiple sensors that can be used for Earth's land, oceans, and atmosphere monitoring. With over 70PB of data produced, Copernicus is one of the biggest civilian data sources in the world. The ultimate success of the Copernicus program depends mainly on the easy, comfortable availability of Copernicus data. The easier the data is available, the more it is used and processed by various applications, and the greater the potential benefits for society. That is why, within the CDSE, Copernicus data are available in an online form, in a way that data can be immediately discovered, delivered, and processed. While the data are the heart of the ecosystem, the CDSE offers much more than simple data access. On the Figure 2 we present the ecosystem with applications that are available for the users and federated services.

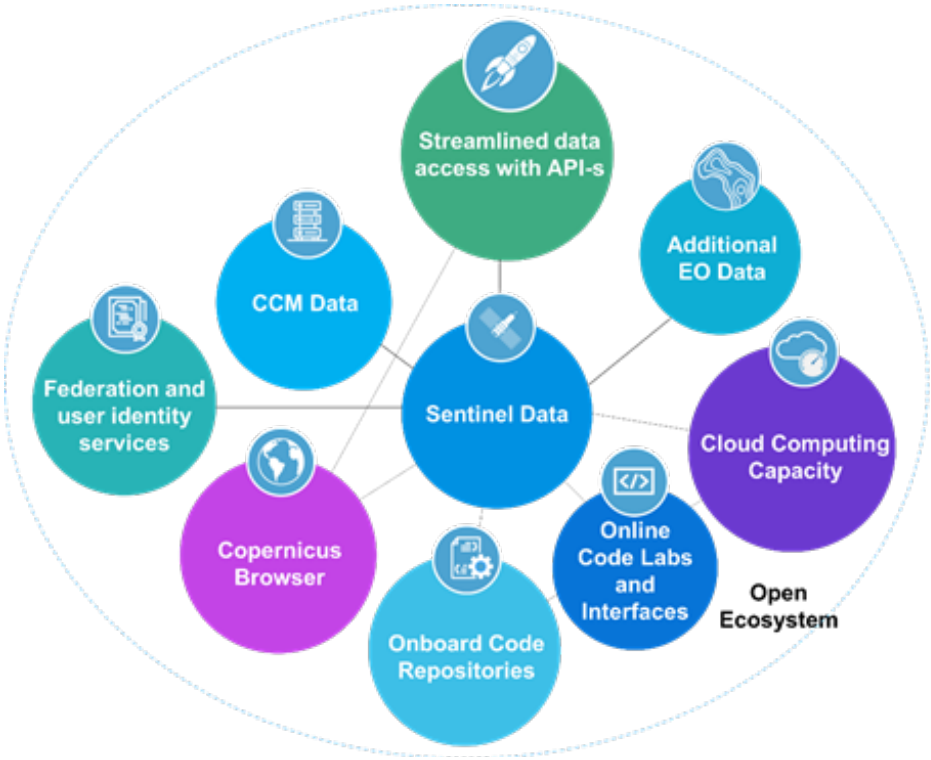


FIGURE 2: Copernicus Data Space Ecosystem in a nutshell.

Even though by providing multiple applications, we reduce the need for simple data download, the CDSE guarantees fast and efficient access to EO data download. The number of products available for the users is constantly growing, resulting in over 45 million new Sentinel products published in 2023. Petabytes of Sentinel data are accessed and downloaded each month. Within this report, we present the statistics for external data download. We can see the spike of demand for data download in CDSE after the end of previous Sentinel Data Access Service in October 2023, and a still increasing demand for data download. Whereas the interest in data is clearly global, the biggest download is still from the European users (see Figure 1). It is worth noting that the statistics for data download do not include data processed and delivered through the Sentinel Hub and openEO, nor the numbers for data retrieved through connected clouds – CloudFerro's cloud and T-Systems' Open Telecom Cloud, and commercial data access through CREODIAS. By the end of 2023 some 15 PB of EO data was delivered to users within the clouds connected to EO data repository for commercial EO based services.

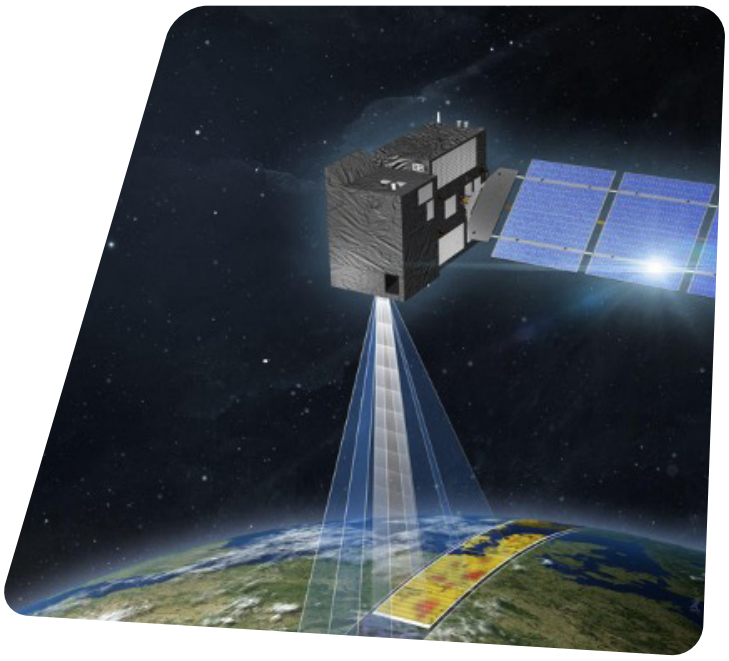


Image source: *esa.int, The Copernicus Carbon Dioxide Monitoring mission, credit: OHB, ESA standard licence*

This is where the big potential of CDSE lies – data can be accessed and processed immediately without a need for download. With streamlined data access services – Sentinel Hub and openEO processing services – users get access to serverless processing and ready-to-use insight on top of the raw data. Moreover, these services can be integrated into any EO service that relies on Copernicus data. In 2023 alone, over 150 million requests were processed by Sentinel Hub, which translates to over 80 – times the area of the Earth's landmass. Additionally, openEO processed over 7.3 million user requests. Importantly, the popularity of these services is growing, as confirmed by the increasing usage of the streamlined data access services.

Starting from January 2023, the system attracted a substantial number of users. At the end of 2023, CDSE had almost 85 000 registered active users[1]. We observed a significant user number increase after the decommissioning of the previous Sentinel Data Access Service in October 2023 (31 000 in December and growing by over 20 000 monthly in the first months of 2024). It is important to note that due to GDPR restrictions, no user accounts were transferred from the former hubs which were operated under the Sentinel Data Access Service, so all registered users are those who have chosen to register afresh, directly with the CDSE.

CDSE started its operations in July 2023, replacing the Sentinel Data Access Service from 1 November 2023 onwards. Therefore, this report covers part of the year of operations. And yet, the numbers we are going to present show that the new approach – based on online availability and many parallel access and analysis methods and tools together with federated clouds – is already vastly successful. While we concentrate on 2023 data, we are also going to present recent trends that tell us that users appreciate the new, easy, and comfortable availability of data. Where possible, we include comparisons with the figures from the 2022 Copernicus Sentinel Data Access Annual Report[2], which was produced by Serco SpA, the prime service provider for the former Sentinel Data Access Service.

This CDSE annual report was compiled by the consortium led by T-Systems as a prime contractor for CDSE. The actual data are delivered by service providers: CloudFerro is responsible for data discovery, access, and retrieval across all elements of the data space; Sinergise manages Sentinel-Hub and Vito handles openEO.

1 Registered active means at least one login to the service.

2 Serco's 2022 Copernicus Sentinel Data Access Report can be viewed at: https://sentinels.copernicus.eu/web/sentinel/-/copernicus-sentinel-data-access-annual-report-2022

2 SYSTEM OVERVIEW

The Copernicus Data Space Ecosystem (CDSE) provides users with free, open, and immediate access to the complete data repository for the Copernicus Sentinel Missions operated by ESA. The services cater to a broad spectrum of demands, ranging from newcomers in the EO field to companies and academic researchers. The objective of the system is to provide users – individuals and organisations – with a platform to quickly search and process EO data in order to provide actionable insights for decision makers. It is the first place where users can access Sentinel data published usually within 30 minutes from the data processing within the production services (and a few hours from sensing time). Importantly, there are no restrictions on who can access the user-level data[3].

Whereas the system allows data to be downloaded in a traditional manner, CDSE is much more than a data download service. It is a comprehensive ecosystem of applications with graphical user interfaces (GUI) and application programming interfaces (API) for accessing, visualizing, and processing Copernicus data. Its mission is to simplify data processing, increase its uptake, and build a European ecosystem for EO data processing. CDSE takes away the technical complexity of accessing and processing data, allowing users to focus on applications. The system is built in a multi-cloud environment, including CloudFerro cloud and Open Telecom Cloud (OTC). The EO Data repository and applications are distributed among CloudFerro Cloud in Warsaw and OTC in Amsterdam, providing data and service redundancy.

The product lifecycle in CDSE starts from the data collection from different sources (part of the ESA Ground Segment), followed by the validation of input data. The validated data are then stored in the EO Data Repositories located in multiple locations (Warsaw and Amsterdam) in either packed or unpacked form according to a defined storage policy. Subsequently, product metadata are published in a common unified catalogue and the stored products are registered in the Traceability Service, for confirmation of the data origin.

After the publication, the product can be discovered by the users and accessed through various applications and interfaces. The figure below presents the data flow within the system, starting from the data retrieval – CDSE retrieves data from the individual mission data production services, stores it in a redundant online repository in accordance with the data policy, and disseminates through multiple interfaces to the users. While users can download the data from CDSE, more importantly, the data can be processed on the fly with streamlined data access and serverless processing applications, such as Sentinel Hub, openEO, Jupyter Hub and on-demand production or in the cloud.

***Image source**: Adobe Stock*

3 However, some products are available for selected users only.

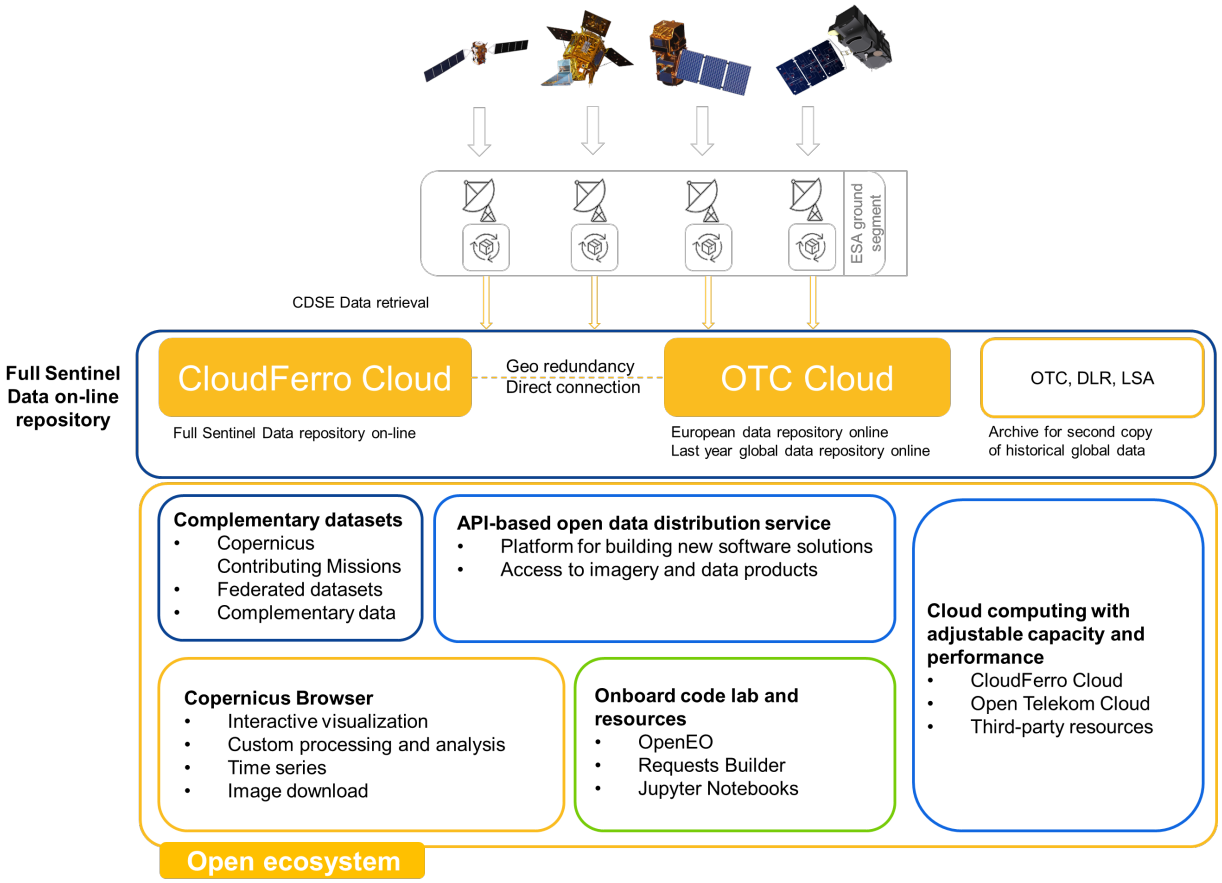


FIGURE 3: The high-level architecture of the CDSE.

Below we present possible ways of accessing the data within the CDSE (Figure 4). Once Sentinel data is stored in the EO data repository, users can search and access it via GUI or API. Importantly, while users can still retrieve a packed (zipped) product using a zipper service, as it was in the previous Data Access Service, users can now directly access a full file or part of it through the S3 interface – a native interface for cloud applications. Moreover, users can access the data through the available applications for streamline data access – Sentinel Hub, openEO, and Jupyter Hub, which provide access to requested parts of the data file and powerful processing capacities. The choice of access methods depends on the user's needs. All the complexity of the data access happens in the background and is no concern for the user.

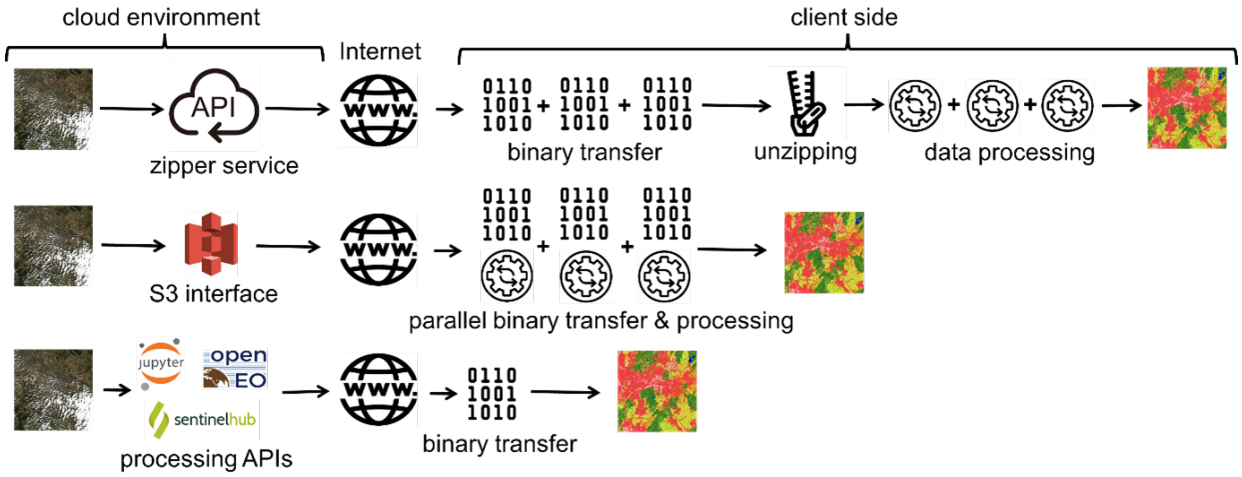


FIGURE 4: Multiple data access and processing scenarios enabled in CDSE.

It is important to note that the Copernicus Data Space Ecosystem is open to everyone. Both public and commercial data sets (e.g. VHR imagery) and services (e.g. applications, cloud computing providers) can join the ecosystem. Inter- operability is ensured by open-source standards implemented such as: STAC, OData, Open Search, and S3 for data access. External developers can also find the corresponding APIs for applications such as Sentinel Hub or openEO, to develop innovations using the data and resources of the CDSE. The available services can be used for both commercial and non-commercial purposes.

Future participation from additional entities, such as third-party providers, is anticipated, happening, and welcomed, enhancing the ecosystem with a diverse array of services, both free and commercial. CREODIAS is the first of these additional providers joining the Copernicus Data Space Ecosystem, allowing users to easily scale up the services implemented in CDSE in an unlimited way on a commercial basis, fostering potential large commercial use cases that require additional processing capacity. The relation between CDSE and commercial services is presented in the Figure 5 below.

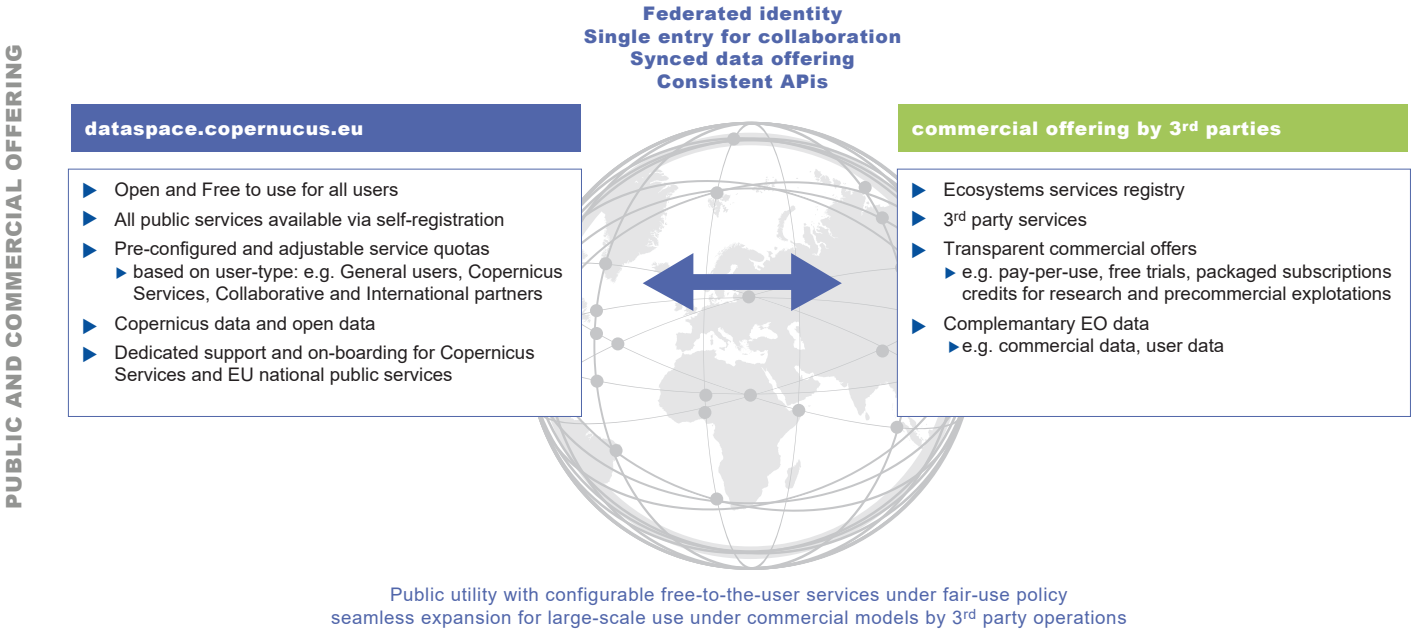


FIGURE 5: CDSE Public and Commercial Service Offering.

The Copernicus Data Space Ecosystem includes all necessary elements enabling growth of the ecosystem, including:

- different cloud computing options from two leading European cloud providers,
- a helpdesk with relevant tutorials and a user forum
- EO specific functionalities like catalogue and data ingestion and access service
- identity and user management
- common billing services
- proactive campaigns and offline/online support events to promote the ecosystem and enhance user engagement

all of which are needed to enhance user engagement and grow European capabilities in the area of data processing.

An overview of the common core, integrated, and third-party services available in the ecosystem is shown in Figure 6 below.

User feedback is highly encouraged and a satisfaction survey is carried out in order to improve the service and make the Copernicus Data Space Ecosystem a valuable asset for all participants.

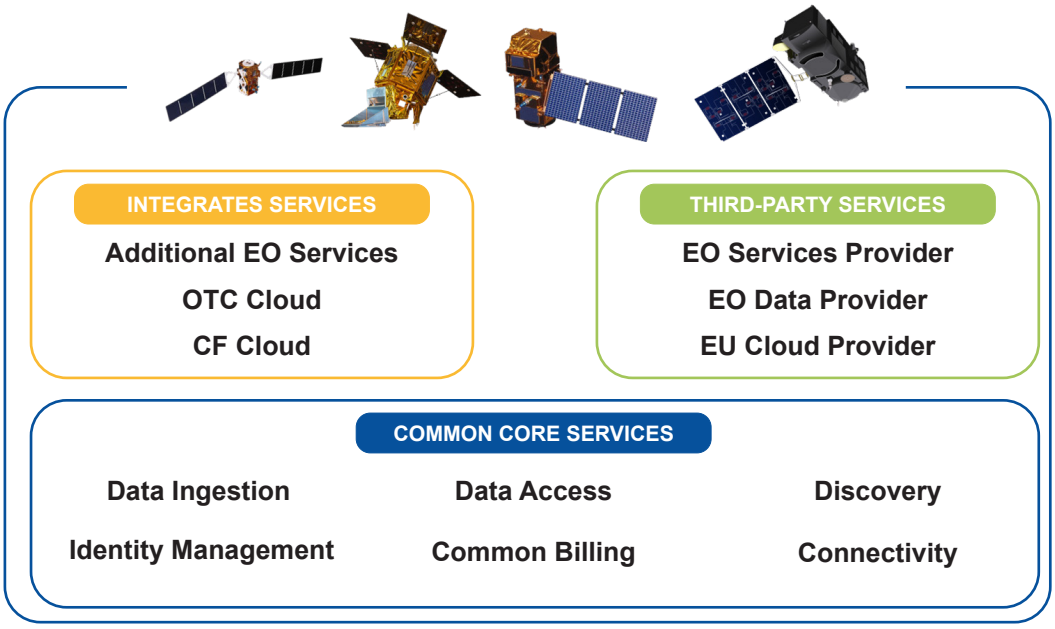


FIGURE 6: Copernicus Data Space Ecosystem services overview.

3 MAIN EVOLUTION MILESTONES OF THE DATA ACCESS SYSTEM IN 2023

Throughout 2023, the Copernicus Data Space Ecosystem services were introduced in a phased approach. In January 2023 – seven weeks after the contract signature – the initial service was made publicly available, opening for users to register and offering access to the new Copernicus Browser for interactive browsing and visualization of a large set of Sentinel data. The data were accessible through the catalogue APIs for OData and OpenSearch.

March 2023

The development of the ecosystem continued. In March, Sentinel-1 and Sentinel-3 user-level products were integrated into the catalogue. A suite of additional APIs, including OData, OpenSearch, and STAC, was unveiled, allowing enhanced user interaction and data retrieval.

April-May 2023

In April, the Traceability API features rolled out, offering users a tool for API interactions with limited functionality as the database began populating. Full product download capabilities became available, adding substantial value to the portal. Additionally, the Copernicus Browser expanded its features to include anonymous access and full product downloads, while the streamlined data access via the Sentinel Hub became accessible to all registered users. The catalogue was expanded to include products from Sentinel-5p, reflecting the service‘s commitment to comprehensive data coverage.

Internally, a working-level dashboard for service integration and status checks was implemented, marking a milestone in the service‘s operational maturity.

July 2023

The service reached operational status at the beginning of July. By that time, the CDSE Web Portal had achieved full functionality, with an integrated user forum and comprehensive documentation. The catalogue service, including all user-level data, was published and accessible, and product download capabilities were extended. An image gallery was added to the portal.

The Copernicus Browser now provided instant access to all types of data and integrated with Data Workspace to support on-demand data production. The streamlined data access and Sentinel Hub services enhanced their offerings with cloud- free mosaics and batch processing APIs.

The service desk reached full integration with available services, including a user forum, adding a community-driven dimension to the ecosystem. The openEO API became officially operational, with a web editor UI and algorithms plaza. The service also introduced a marketplace for federated ecosystem members, fostering a collaborative and dynamic ecosystem in the future. In addition to that, the Jupyter Hub became operational, offering a rich resource for learning and experimenting with different APIs.

Data Workspace launched a management UI for Product Generation as a Service (PGaaS), and traceability was augmented with a search UI and API. The on-demand processing service also came online, allowing users to generate value added products through an API, using non-ESA IPF processors.

After achieving the operational status, the stabilization period began, during which the ecosystem services were fine-tuned, ensuring stability and performance optimization. The user community continued to grow, providing valuable feedback for further improvements. This included new functionalities in already available services and documentation. The streamlined data access and Sentinel Hub were further developed, and attractive components, such as quarterly global mosaics were added.

September 2023

The catalogue continued to evolve with new datasets being available (e.g., Sentinel engineering and auxiliary data).

November 2023

As of November 2023, the CDSE became the sole source for accessing the Copernicus Sentinel data generated by ESA. The service replaced the previous Data Access Service (Open Access Hub). The transition was smooth, confirming the service maturity and comprehensive offerings.

December 2023

The year ended with the traceability service beginning to populate the database with historical traces for Sentinel products and extending its capabilities to other ESA Ground Segment services. The dashboard service unveiled an executive dashboard for users, offering an overview of the ecosystem's operations.

It is worth noting that the service development has not ended – it will continue to grow as services and datasets are continuously added and improved. The high-level roadmaps for the last year and for the year to come are presented below.

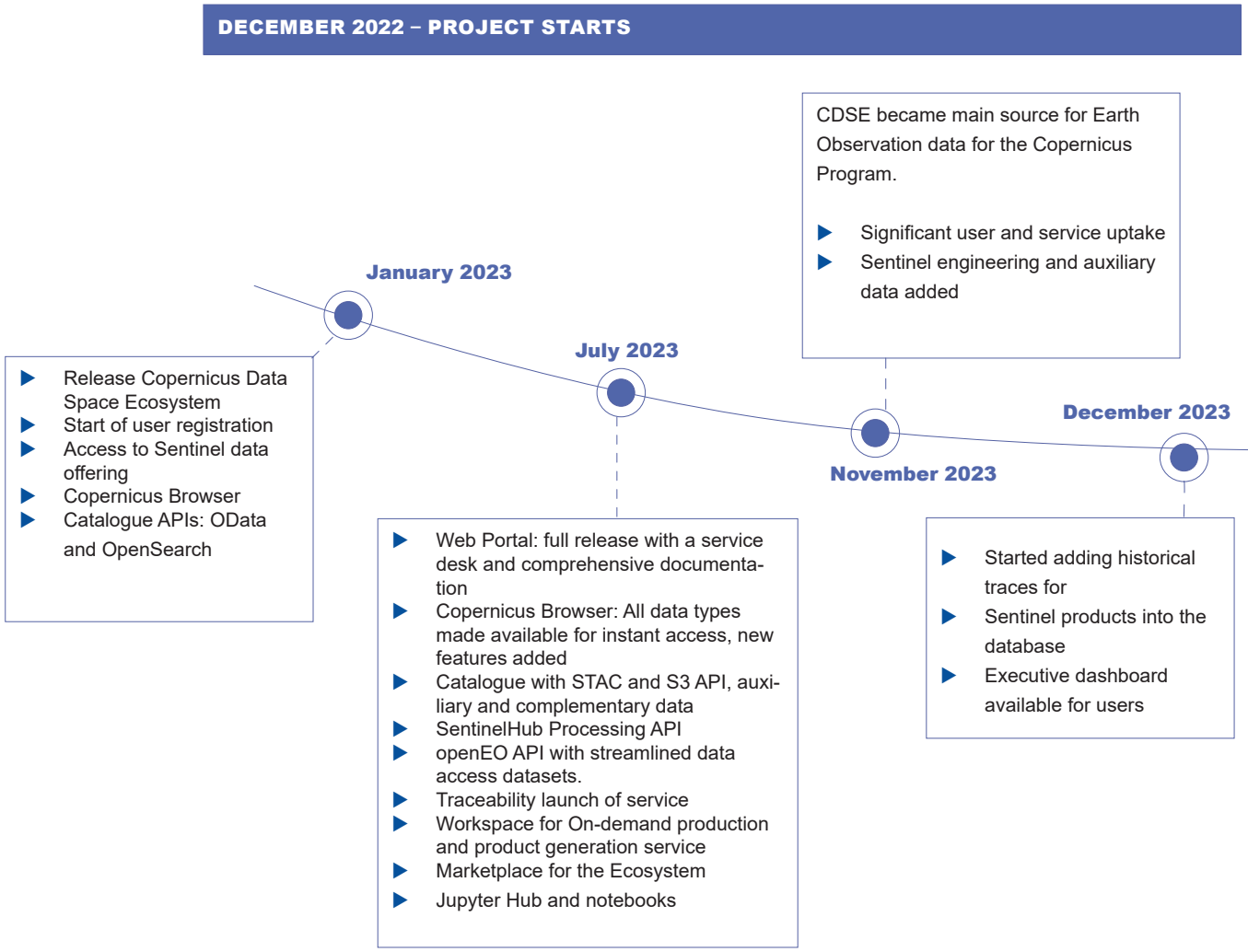


FIGURE 7: Main evolution milestones of the Copernicus Data Space Ecosystem in 2023.

4 OUTLOOK OF THE DATA ACCESS SYSTEM FOR 2024

After the extensive phase-in performed in 2023, the focus of all consortium members is on finalizing the remaining phase-in actions. The consortium is continuously optimizing the platform to ensure service stability, enhance platform performance and to provide a superb end-user experience to meet the sharply increasing visitor needs, while preparing for a massive intake of users over the coming months.

CDSE Roadmap	Delivery outlook
Copernicus Contributing Missions	▶ First sets of Copernicus Contributing Missions (CCM) data have been made available to users since March 2024. The overall release process covers several technical steps, including data ingestion of remaining data sets, catalogue indexing, product format conversion to COG, adding visibility layer to Copernicus Browser ▶ The following CCM data sets are available on Copernicus Data Space Ecosystem: VHR 2021, VHR 2018, VHR 2015, COP DEM, SAR Sea Ice
On-Demand Production for Sentinel-1, Sentinel-2, and Sentinel-3	▶ On-Demand Production for Sentinel-1, Sentinel-2 and Sentinel-3 is planned to release in 2024
STAC API evolution	▶ STAC API service has been available since May 2023, and was being optimized to some extent until December 2023. Additionally, new STAC assets and attributes are planned to be released in CDSE. The objective is to enrich CDSE with STAC reference API for the EO users in 2024
Sentinel-1 SLC bursts	▶ Sentinel-1 SLC bursts are planned to be delivered to the users in 2024
Access to Sentinel-1 original compressed data	▶ The following product types are provided as compressed zip since March 2024: S-1 RAW, S-1 SLC, S-1 GRD
New data and missions	▶ Sentinel-2 Collection 1 ▶ Sentinel-2C missions is planned to be made available for users in Q4 2024 (there are 2-3 months of tests before publishing products)
CSV Catalogue view	▶ Ability to download the CDSE catalogue in csv format, refreshed daily, is provided to users starting from March 2024
Subscriptions	▶ Subscription services (PUSH and PULL) allow users to receive notifications in an automated way about newly added products to the CDSE catalogue, according to the set of filter parameters supplied within the subscription request

CDSE Roadmap	Delivery outlook
Global mosaics	▶ Further generation of Sentinel-2 L2A quarterly mosaics covering the whole archive of S-2 products ▶ Generation of Sentinel-1 GRD mosaics covering the whole archive of S-1 products
Common billing	▶ Users of commercial services on CREODIAS can expect a unified billing, reporting, and invoicing for commercial services, beginning with the use of openEO credits, Sentinel Hub credits and cloud resources. The service is intended to be further extended for other third parties to integrate their services on CREODIAS according to demand
Availability of historical traces	▶ The trace generation process to ensure authenticity for all Sentinel user-level data on CDSE began in Q4 2023 and will last until Q3 2024
Executive dashboard enhancements	▶ CDSE continues the development and evolution of the next-level statistics and metrics as a natural progression of the service

TABLE 1: Upcoming improvements in 2024.

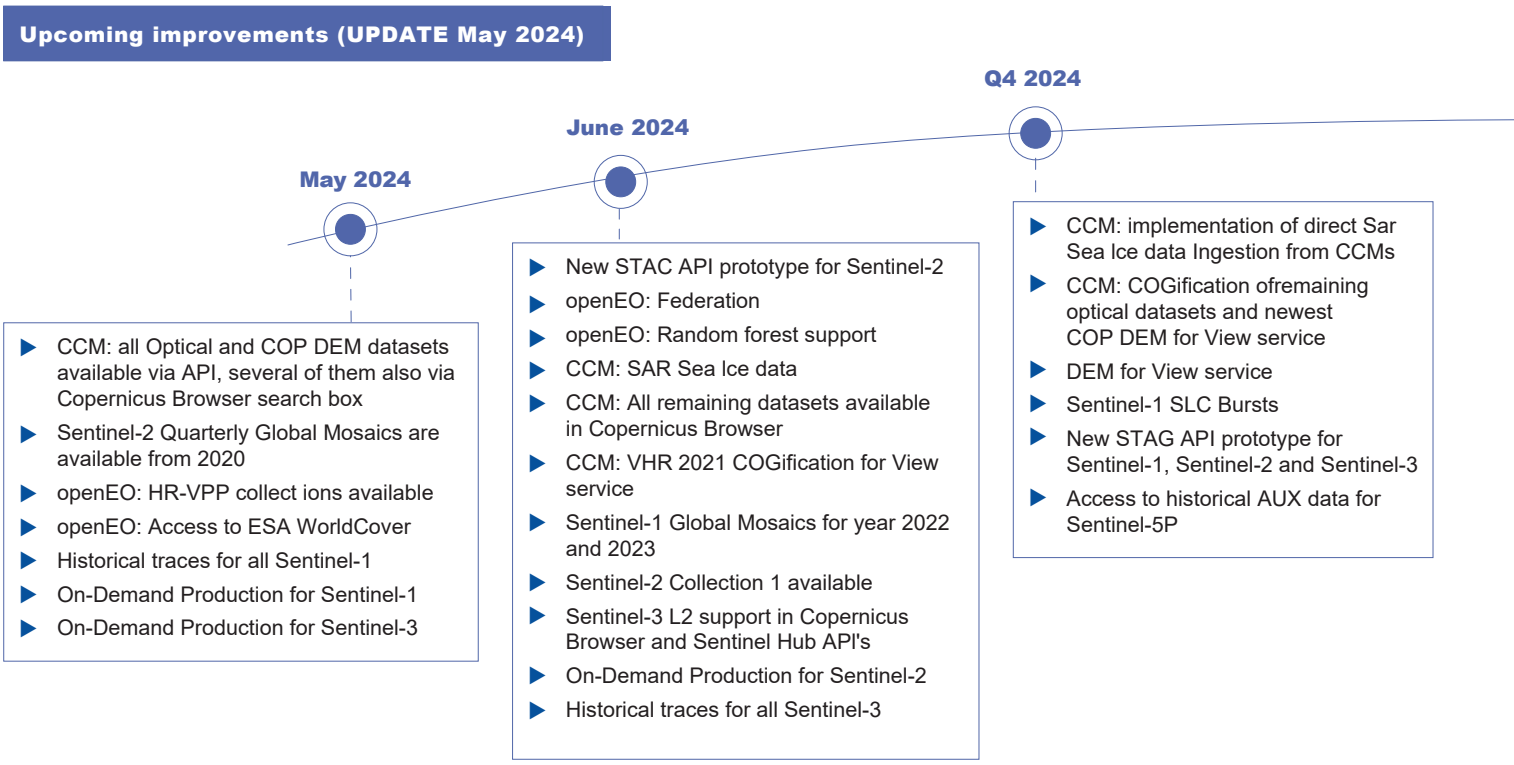


FIGURE 8: Main evolution milestones of the Copernicus Data Space Ecosystem in 2024.

5 USER GROWTH AND TYPOLOGY

In 2023, the number of users who registered for an account on the CDSE increased remarkably quickly within the year, rising from zero at the start of operations to nearly 85,000 by the end of the year. This section provides a detailed analysis of that growth.

It is recalled that none of the user accounts from the former Sentinel Data Access Service was migrated to the CDSE, due to considerations connected to the EU General Data Protection Regulation (GDPR).

5.1. Registered Users

The graphic below shows the trend of user registrations on the CDSE in 2023, with the cumulative number reached by the end of the year. The number of registered users in the first 9 months ranged from 300 to 4,000 per month. There was then a significant increase in the rate of registrations in the last 3 months of the year. It is assumed the reason for the large increase was the closure of the previous Sentinel Data Access Service, and the Copernicus Data Space Ecosystem becoming the sole source of Copernicus Sentinel data provided by ESA. It is worth noting that the increase in registrations observed in the last months of 2023 continued into early 2024, leading to the total number of registrations exceeding 140,000 in Q1 2024.

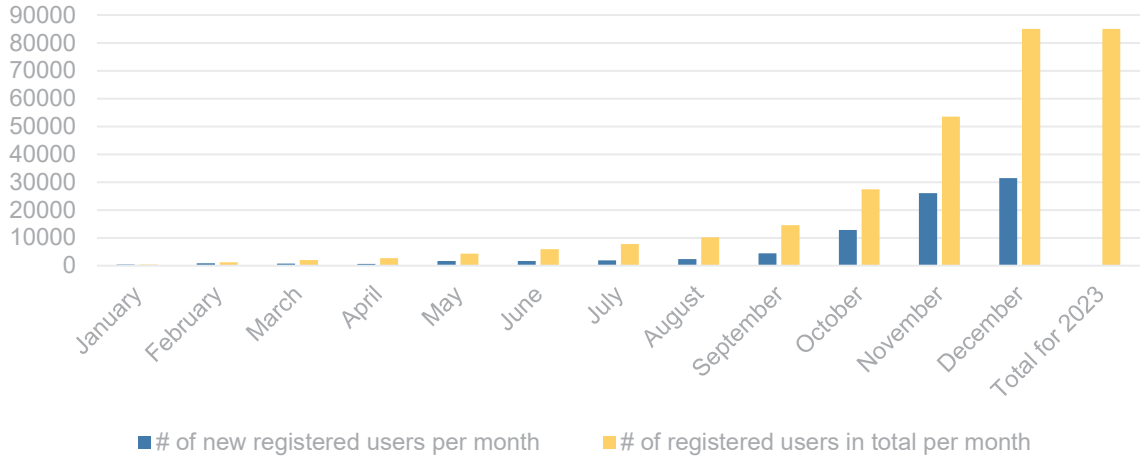


FIGURE 9: Registered users per month and total for 2023.

The user management system includes the grouping of users into roles. For each role, there are defined access and performance levels, such as the volume of downloads per month that the user is entitled to from the free quota made available through the public funding. On registration, users are by default assigned the 'Copernicus General Users' role. Other roles may be assigned to qualified users, following a request by ESA. This approach replaces the need for multiple portals and endpoints with different data access policies for different users, as was the case under the previous Sentinel Data Access Service.

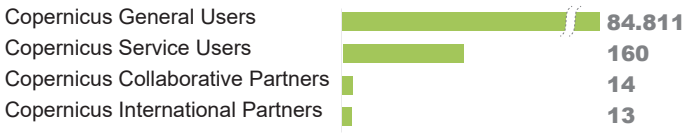


FIGURE 10: Registered users per role (as of 2023.12.31).

During the registration process, users are encouraged to identify their thematic activity preferences from a range of options. It is important to mention that users are not obliged to select a preference in this section.

Figure 11 below shows that most of the user engagement (87%) is within five thematic activities: Land, Research and innovation, Climate Change, Environmental compliance, and Marine environment, maritime affairs, and fisheries. When the statistics are compared to those from Serco's 2022 Annual Report, it shows the thematic focus has not changed significantly. However, the Air quality theme seems less represented amongst the first-year registrations for the CDSE.

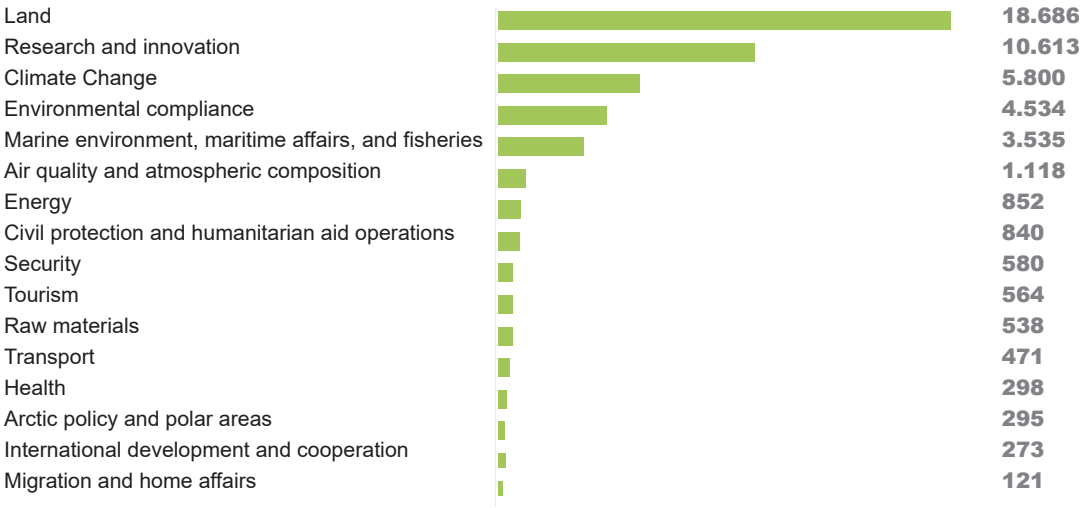


FIGURE 11: Registered users per thematic activity.

Figure 12 below illustrates the number of user registrations which were made in each continent during the year. It is highlighted that the information about the location of user accounts is provided by users during the registration process and no additional checks on location (e.g. IP address) are carried out.

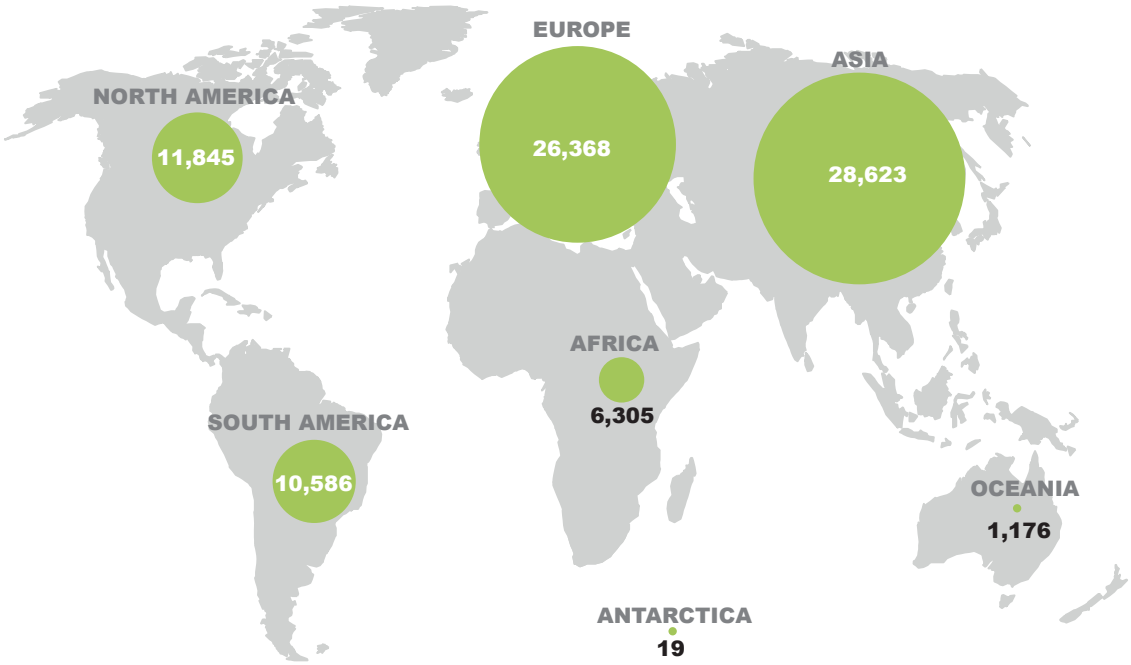


FIGURE 12: Number of registered users per continent as of December 2023.

Another perspective on the global penetration is to count the number of countries in which there are more than 100 user registrations. Figure 13 illustrates the monthly cumulative increase in the number of countries that exceeded this threshold. Starting from zero in January, there was a stable trend for most of the year, and then again from October onwards, the number of countries crossing the threshold significantly increased and continued on that trajectory. Again, it is noted that this trend continued in the first quarter of 2024, giving a positive outlook for the future, in terms of user take-up.

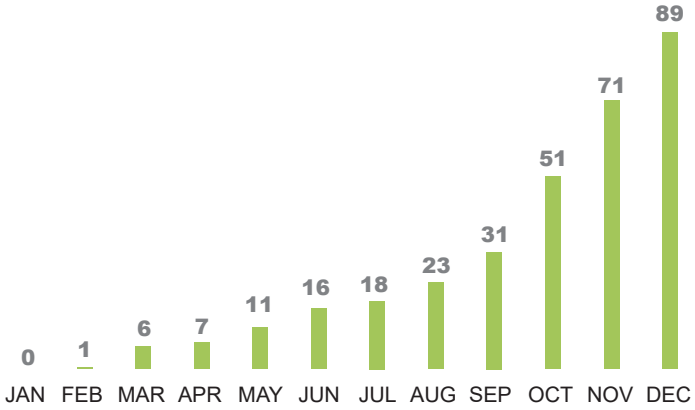


FIGURE 13:
Number of countries exceeding 100 users per month in 2023.

Figure 14 presents the ESA and European Union member states which have the highest numbers of registered users.

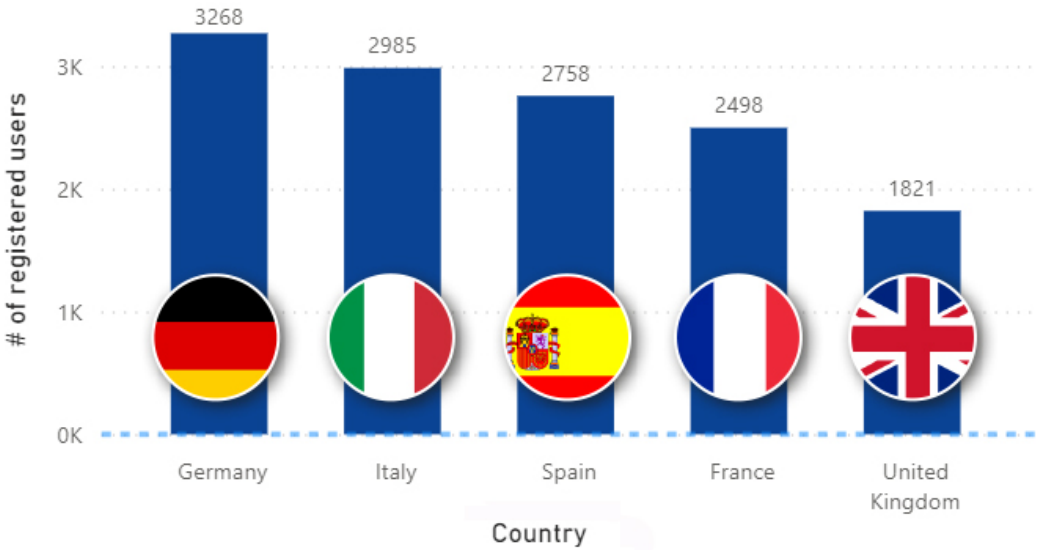


FIGURE 14: 5 EU and ESA member states with the highest number of registered users (Dec 2023).

5.2. Core Data Offer

This section presents the statistics regarding the amount of data available in the CDSE from the core data offering, namely Sentinel-1, Sentinel-2, Sentinel-3 and Sentinel-5P.

The Copernicus Sentinel-1 mission consists of two polar-orbiting satellites that operate both day and night. These satellites employ C-band synthetic aperture radar imaging, enabling them to acquire images under all weather conditions. The mission features C-band imaging in four distinct modes, offering varying resolutions (as fine as 5 meters) and coverage areas (up to 400 km). It also provides dual polarization capabilities, short revisit intervals, and prompt product delivery. Additionally, each observation is supported by precise data on spacecraft position and attitude. Notably, the Sentinel-1B satellite suffered a power failure on December 23, 2021, and is no longer operational.

The Copernicus Sentinel-2 mission features wide-swath, high-resolution, multi-spectral imaging. The mission includes two satellites flying in the same orbit, phased 180° apart, designed to achieve a high revisit frequency of 5 days at the Equator. Equipped with an optical instrument payload, Sentinel-2 samples 13 spectral bands, which include four bands at a 10 m spatial resolution, six bands at 20 m, and three bands at 60 m. The orbital swath width of the satellites is 290 km.

In addition to the initial processing of the products, the CDSE provides the Copernicus Sentinel-2 Collection-1. This collection, currently in development over the Sentinel-2 historical archive, aims to deliver consistent time series from both Sentinel-2A and Sentinel-2B satellites with a uniform processing baseline and optimized calibration. This enhancement focuses particularly on improving geometric performance, among other aspects. All historical data from the launch of the Sentinel-2A satellite in 2015 up to December 2021 are planned to be reprocessed and made available.

The Copernicus Sentinel-3 mission's primary goal is to measure sea surface topography, sea and land surface temperature, and ocean and land surface colour with high accuracy and reliability. This data is essential for supporting ocean forecasting systems, environmental monitoring, and climate monitoring. Jointly managed by the European Space Agency (ESA) and the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), the mission delivers operational ocean and land observation services. It utilizes two spacecrafts, each equipped with four main instruments: the Ocean and Land Colour Instrument (OLCI), the Sea and Land Surface Temperature Instrument (SLSTR), the SAR Radar Altimeter (SRAL), and the Microwave Radiometer (MWR).
It is worth noting that some product types of Sentinel-3 have undergone reprocessing to new baselines.

The Copernicus Sentinel-5 Precursor (Sentinel-5P) mission is the first Copernicus mission dedicated to monitoring our atmosphere. Its main objective is to conduct high spatiotemporal resolution atmospheric measurements that are critical for air quality assessment, ozone and UV radiation monitoring, and climate forecasting. The Sentinel-5P mission features various data products resulting from the TROPOMI instrument's three processing levels: Level-1B, and Level-2.

Mission	No. of user-level data published		% for 2023 of total number published since mission start	Volume of user-level data published [TB]		% for 2023 of total volume published since mission start
	2023	Total - since mission start	2023 vs total	2023	Total - since mission start	2023 vs total
S1	3,919,503	11,313,589	35%	5,028.60	27,093.20	19%
S2	34,317,458	59,959,211	57%	20,268.75	33,891.49	60%
S3	4,894,779	17,296,890	28%	1,092.57	5,159.00	21%
S5P	1,317,207	4,180,775	32%	889.66	1,682.24	53%
ALL	**44,448,947**	**92,750,465**	**48%**	**27,279.59**	**67,825.94**	**40%**

TABLE 2: The total number and volume of Sentinel products published in the CDSE in 2023 compared to the cumulative number and volume of products since the start of mission operations.

Since the start of the CDSE Service in December 2022 until the end of 2023, a total of 45,915,781 Copernicus Sentinel user-level data products were published, with a total data volume of 28,140 TB (Table 3). 97% of these products, in terms of number and volume, were published in 2023, with a total of 44,448,947 data packages published during the year (27,280 TB in volume). This represents 48% of the total number of Copernicus Sentinel user-level data made available since the start of Sentinel operations in 2014, and 40% of the total volume made available (Table 2).

The products published in 2023 include a large amount of archive data supplemented. Significant differences in percentages for the number of products and volume (e.g., for S1 and S5p) arise.

It is also worth emphasizing that the volumes published in the early months of the Service are much larger than the nominal, regular output of the Sentinels ground segment due to the migration of data from the legacy service to complete the data offer with respect to the complete historic record of data from the Sentinels.

To provide a full and consistent dataset offering, the CDSE includes both standard and reprocessed formats of the mission data. Table 3 shows the number and volume of data from each mission which was published during the year, and the totals published since the start of the CDSE project in December 2022. The Table shows separately the figures for the Sentinel-2 and Sentinel-3 standard user-level products (STRD) and reprocessed data (RPRO) which was published in parallel.

Mission	No. of user-level data published		% for 2023 of total number published on CDSE	Volume of user-level data published [TB]		% for 2023 of total volume published on CDSE
	2023	Since project start (Dec 2022)	2023 vs project start	2023	Since project start (Dec 2022)	2023 vs project start
S1	3,919,503	3,986,562	98%	5,028.60	5,219.79	96%
S2 STRD	13,715,948	14,596,366	94%	8,339.07	8,881.93	94%
S2 RPRO	20,601,510	20,601,510	100%	11,929.68	11,929.68	100%
S3 STRD	4,333,946	4,704,094	92%	959.10	1,037.99	92%
S3 RPRO	560,833	564,356	99%	133.48	141.99	94%
S5P	1,317,207	1,462,893	90%	889.66	928.72	96%
ALL	**44,448,947**	**45,915,781**	**97%**	**27,279.59**	**28,140.10**	**97%**

TABLE 3: Overall number and volume of published user-level data on the CDSE in 2023 compared to data published since the project start in December 2022.

Table 4 and Table 5 show, respectively, the daily average volumes and number of products which were published per mission on the CDSE in December 2023 compared to December 2022, when the data was published under the former Sentinel Data Access Service. A significant increase can be seen in the totals for both the daily volume and number of products published in December 2023 compared to December 2022, largely accounted for by the Sentinel-2 reprocessed data, which comprised almost half of all data published in the year.

Mission	Daily average volume published in Dec 2023 [TB]		Daily average Volume published in Dec 2022 [TB]*	
	Absolute number	Relative to all missions	Absolute number	Relative to all missions
S1	7.23	17%	3.94	22%
S2 STRD	10.34	24%	11.15	61%
S2 RPRO	20.89	49%	-	-
S3 STRD	2.47	6%	2.59	14%
S3 RPRO	0.45	1%	-	-
S5P	1.17	3%	0.46	3%
ALL	**42.55**	**100%**	**18.15**	**100%**

TABLE 4: Average volume of user-level data published per day in December 2022 and December 2023, with percentage splits per Sentinel mission (the 2022 data come from the 2022 Copernicus Sentinel Data Access Annual Report). The percentages indicate the share of data published by each mission relative to the total data published from all missions combined.

Mission	Daily average number of products published in Dec 2023		Daily average number of products published in Dec 2022 *	
	Absolute number	Relative to all missions	Absolute number	Relative to all missions
S1	3,753	5%	2,216	7%
S2 STRD	18,137	25%	19,445	60%
S2 RPRO	35,691	48%	-	-
S3 STRD	11,532	16%	8,883	27%
S3 RPRO	1,247	2%	-	-
S5P	3,493	5%	1,808	6%
ALL	**73,853**	**100%**	**32,353**	**100%**

TABLE 5: Daily average number of user-level data published per mission during December 2022 and December 2023, with percentage splits per Sentinel mission (the 2022 data come from the 2022 Copernicus Sentinel Data Access Annual Report). The percentages indicate the share of data published by each mission relative to the total data published from all missions combined.

*- data from the 2022 Copernicus Sentinel Data Access Annual Report
STRD – stands for standard user-level data only
RPRO – stands for reprocessed user-level data only

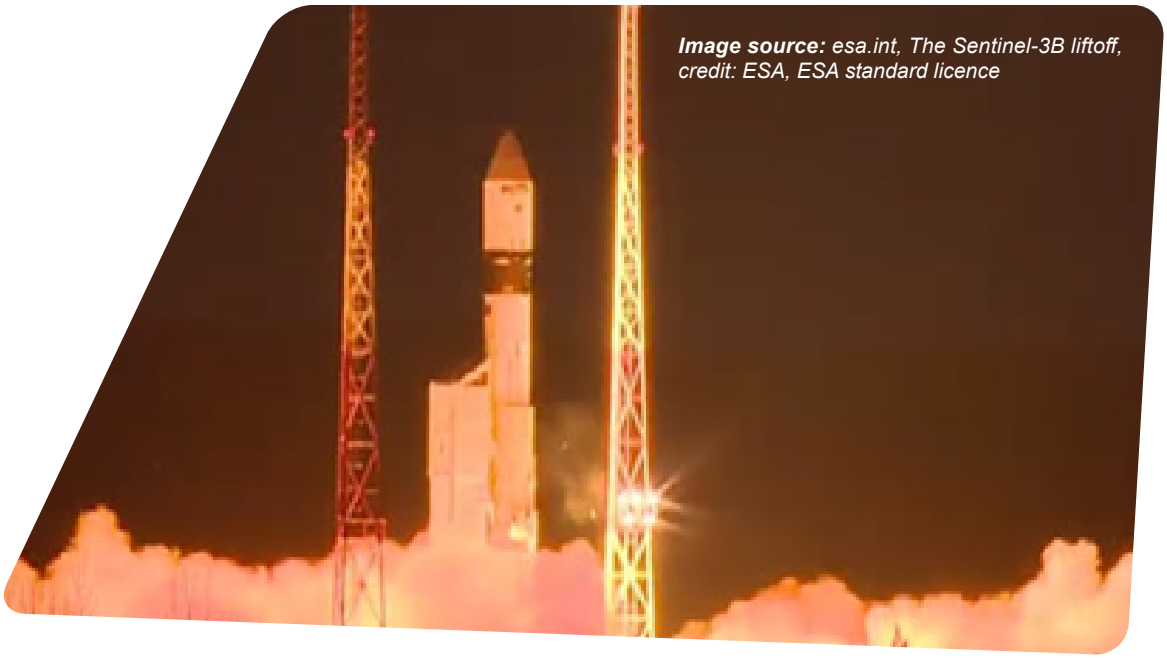


Image source: *esa.int, The Sentinel-3B liftoff, credit: ESA, ESA standard licence*

Table 6 lists the number and volume of published user-level data per month and per Sentinel mission in 2023. Figure 15 and Figure 16 illustrate the same data, showing the trends in count and volume, respectively, throughout the year. These figures represent the total of all individual user-level data types published per mission, including both –A and –B satellites where applicable (i.e., Sentinel-1, Sentinel-2, and Sentinel-3). It is recalled that since Sentinel-1B experienced a failure on December 23, 2021, only fresh data from Sentinel-1A was published.

Month	S1		S2		S3		S5P	
	count	TB	count	TB	count	TB	count	TB
January	69,977	203.5	1,402,370	864.8	378,711	90.5	65,302	23.2
February	61,432	177.4	3,329,075	1,940.3	341,655	81.9	87,300	78.8
March	85,285	216.8	4,042,822	2,442.8	372,578	91.4	220,774	258.2
April	170,670	264.4	3,649,662	2,240.4	363,003	88.6	162,520	240.1
May*	1,253,295	1,252.9	1,825,866	1,092.0	368,949	89.9	103,988	50.7
June*	1,500,980	1,453.3	2,848,633	1,639.7	377,088	91.3	81,760	28.1
July	261,235	379.7	3,228,148	1,884.8	387,678	94.6	99,675	35.3
August	85,994	212.9	2,481,418	1,471.6	394,671	94.1	91,323	32.7
September	87,351	214.6	2,942,979	1,702.0	377,229	90.4	100,576	35.8
October	133,255	218.2	3,593,460	2,079.9	765,029	102.7	103,630	36.4
November	102,940	214.0	3,304,490	1,942.5	376,388	87.1	98,312	34.6
December	107,089	220.9	1,668,535	967.9	391,800	90.0	102,047	35.8
Total	**3,919,503**	**5,028.6**	**34,317,458**	**20,268.8**	**4,894,779**	**1,092.6**	**1,317,207**	**889.7**

TABLE 6: Monthly number and volume of published user-level data per Sentinel mission in 2023.

* The higher values of number and volume of S1 products in May and June are in large due to the generation and ingestion of S1 GRD COG products.

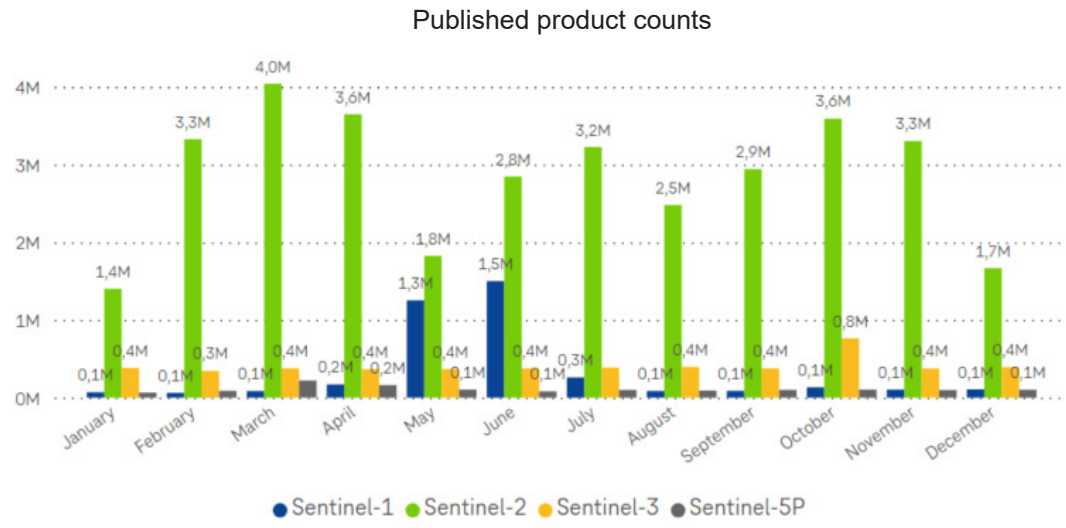


FIGURE 15: Development of the monthly number of published product counts per Sentinel mission in 2023. 'M' signifies millions of products

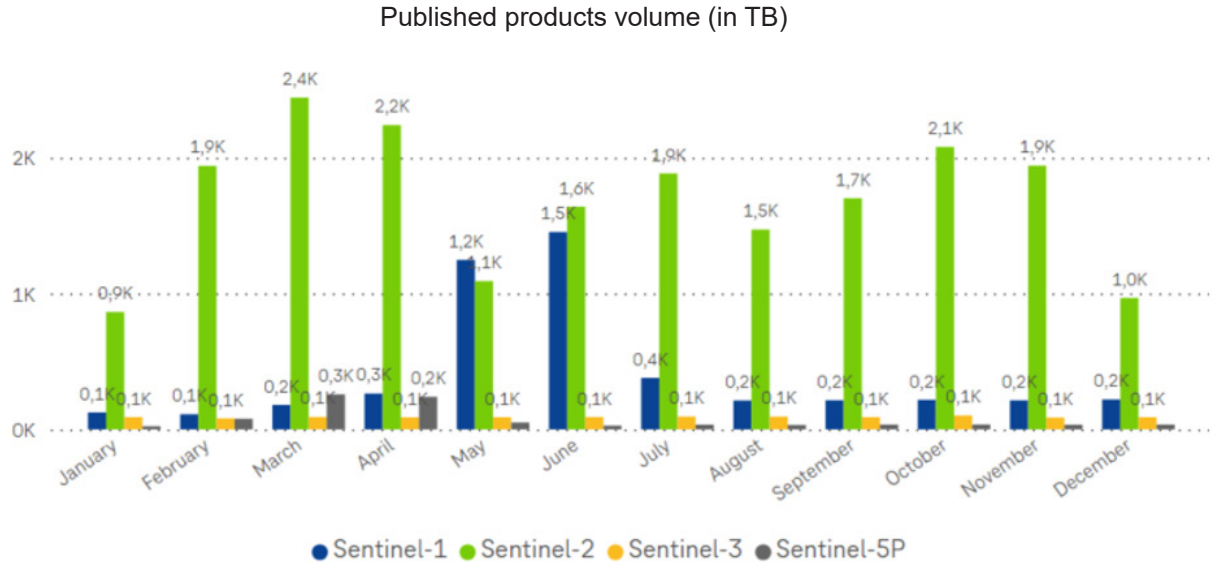


FIGURE 16: Development of the monthly volume of published user-level data per Sentinel mission in 2023. ‚K' signifies thousands of TB

The tables and graphs below present more specific detail on the monthly counts and volumes of user-level data published on CDSE for each Sentinel mission.

Sentinel-1:

The number of products published for Sentinel-1 remained quite stable throughout the year, except in May and June, when a large amount of missing data was supplemented. During this period, Sentinel-1 GRD data in COG (Cloud Optimized GeoTiff) format was also generated and added to the ecosystem. This data is now available for the entire archive on a global scale, whilst the original GRD products in SAFE format are only available as a rolling archive for the past year with the option to order data from cold archive. Table 7 shows the number and volume of published Sentinel-1 products, indicating how much of it was data in COG (Cloud Optimized GeoTiff) format. The first two columns of this table (i.e., the count and volume of all Sentinel-1 user-level data published per month) are illustrated in the bar charts of Figure 17.

Month	S1		S1-COG		% of COGs
	count	TB	count	TB	(count)
January	69,977	203.46	262	0.34	0.4%
February	61,432	177.43	119	0.15	0.2%
March	85,285	216.82	15,323	14.81	18%
April	170,670	264.36	103,302	69.40	61%
May	1,253,295	1,252.90	1,187,520	1,059.79	95%
June	1,500,980	1,453.34	1,439,417	1,302.33	96%
July	261,235	379.75	196,853	191.07	75%
August	85,994	212.90	19,109	18.68	22%
September	87,351	214.60	19,401	18.81	22%
October	133,255	218.17	19,960	19.38	15%
November	102,940	214.02	19,070	18.48	19%
December	107,089	220.86	19,684	19.01	18%
Total	**3,919,503**	**5,028.60**	**3,040,020**	**2,732.24**	**78%**

TABLE 7: Monthly number and volume of user-level Sentinel-1 data published in 2023 differentiated between COG and non-COG products.

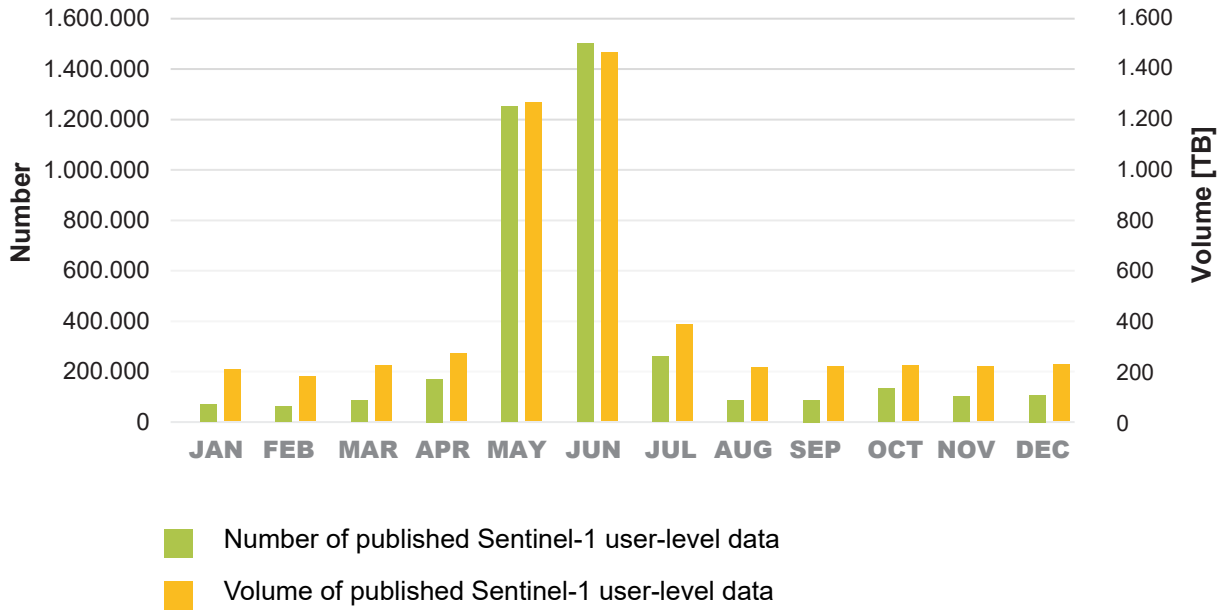


FIGURE 17: Monthly publication trends for the number and volume of Sentinel-1 in 2023. The high number of published products in May and June is due to the replenishment of Sentinel-1 products on the Copernicus Data Space Ecosystem.

Sentinel-2:

Table 8 presents a monthly breakdown of the quantity and volume of published Sentinel-2 data. Two main factors impacted the monthly variability in the count and volume of published Sentinel-2 products. Firstly, there was an intensive effort to supplement missing Sentinel-2 products at the beginning of 2023, peaking in March and April, before stabilizing to a consistent count and volume of fresh data by the end of the year.

Notably, a reprocessing campaign for Sentinel-2, known as 'The Sentinel-2 Collection 1', has been running in parallel to the standard production.

This reprocessed data is gradually being ingested into CDSE to provide a comprehensive and consistent dataset offering. Thus, both standard user-level data (older processing baselines) and reprocessed data are available within CDSE. As shown in Table 8, reprocessed data could account for up to five times more than the standard user-level data published (e.g., in November 2023).

Figure 18 displays the combined count and volume of Sentinel-2 data, including both standard user-level data and reprocessed data, while Figure 19 shows the standard user-level data only.

Month	S2 STRD		S2 RPRO		% of reprocessed products to non-reprocessed (count)
	count	TB	count	TB	
January	1,132,885	708.33	269,485	156.47	24%
February	1,145,298	706.41	2,183,777	1,233.90	191%
March	1,952,435	1,244.84	2,090,387	1,197.92	107%
April	2,284,784	1,440.87	1,364,878	799.54	60%
May	1,369,909	826.42	455,957	265.57	33%
June	991,573	585.39	1,857,060	1,054.32	187%
July	1,034,257	615.29	2,193,891	1,269.55	212%
August	969,079	571.98	1,512,339	899.65	156%
September	918,876	541.03	2,024,103	1,160.97	220%
October	768,226	443.55	2,825,234	1,636.37	368%
November	586,506	334.63	2,717,984	1,607.92	463%
December	562,120	320.35	1,106,415	647.51	197%
Total	**13,715,948**	**8,339.07**	**20,601,510**	**11,929.68**	**150%**

TABLE 8: Monthly number and volume of published user-level Sentinel-2 data differentiated between reprocessed and standard products.

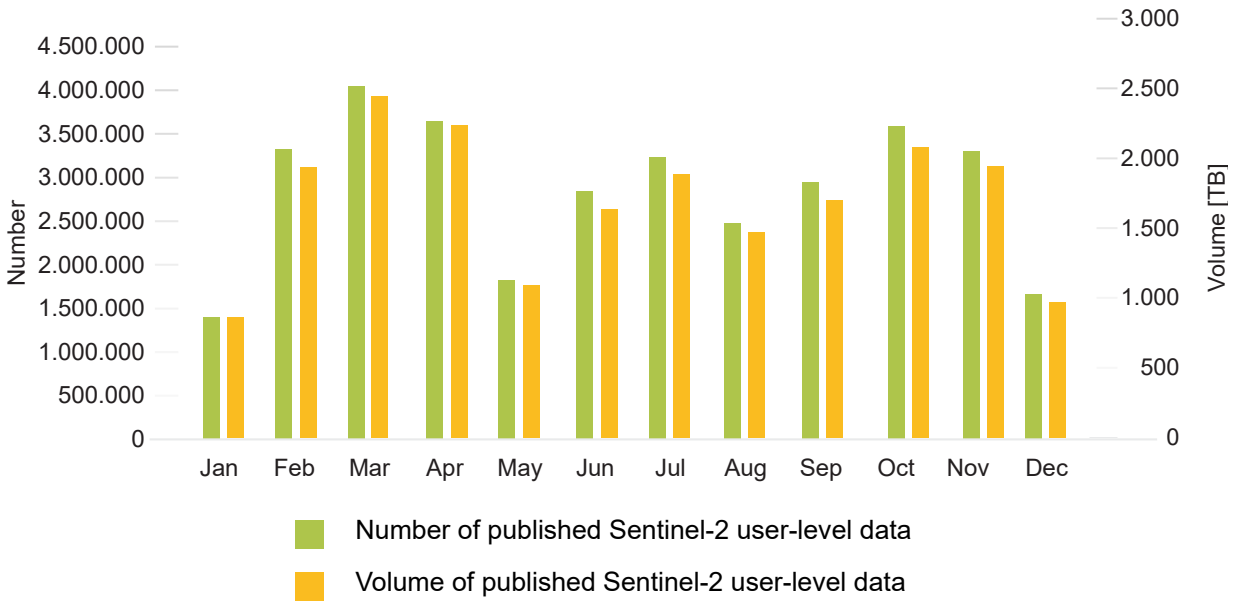


FIGURE 18: Monthly number and volume publication trend for Sentinel-2 in 2023.

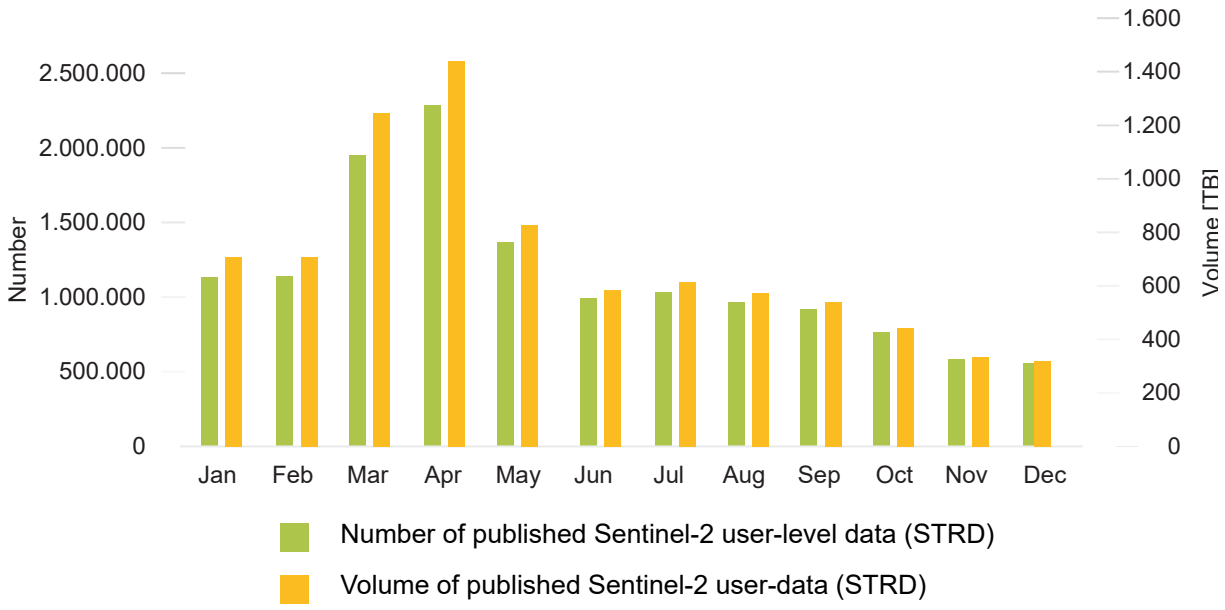


FIGURE 19: Monthly number and volume publication trend for Sentinel-2 standard data in 2023 (standard user-level data).

Sentinel-3:

Table 9 presents a monthly breakdown of the quantity and volume of published Sentinel-3 data. The count and volume for standard user-level data remained almost stable throughout the year. Sentinel-3 has also undergone a reprocessing campaign, with both standard and reprocessed data available in the ecosystem. Most of the reprocessed data were ingested into the CDSE in October 2023, constituting 54% of all Sentinel-3 data published that month.

Figure 20 shows the count and volume of all Sentinel-3 data (standard and reprocessed) published in CDSE. Additionally, Table 15 and Figure 16 detail how these data volumes are distributed among Sentinel-3 products based on OLCI, SLSTR, and SRAL, as well as data produced from the fusion of OLCI and SLSTR, called SYNERGY.

Month	S3 STRD		S3 RPRO		% of reprocessed products to non-reprocessed
	count	TB	count	TB	
January	375,040.00	81.68	3,671.00	8.81	1%
February	337,516.00	73.84	4,139.00	8.06	1%
March	369,038.00	82.62	3,540.00	8.83	1%
April	357,358.00	79.97	5,645.00	8.64	2%
May	359,459.00	80.81	9,490.00	9.06	3%
June	368,419.00	82.64	8,669.00	8.71	2%
July	378,817.00	85.61	8,861.00	8.99	2%
August	385,822.00	85.10	8,849.00	8.99	2%
September	358,595.00	80.00	18,634.00	10.36	5%
October	351,830.00	76.95	413,199.00	25.74	117%
November	338,916.00	73.72	37,472.00	13.42	11%
December	353,136.00	76.15	38,664.00	13.88	11%
Total	**4,333,946.00**	**959.10**	**560,833.00**	**133**	**13%**

TABLE 9: Monthly number and volume of published user-level Sentinel-3 data differentiated between reprocessed and standard products.

STRD – stands for standard user-level data
RPRO – stands for reprocessed user-level data

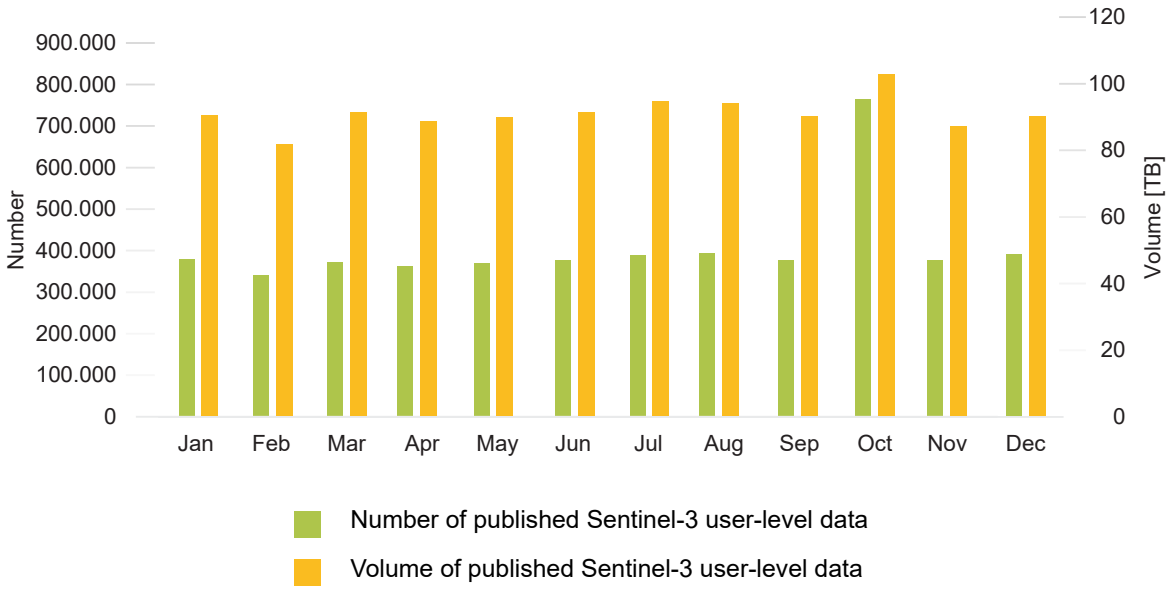


FIGURE 20: Monthly number and volume publication trend for Sentinel-3 in 2023.

Month	TB			
	S-3 OLCI	S-3 SLSTR	S-3 SRAL	S-3 SYNERGY
January	35.2	30.6	16.7	8.0
February	32.0	27.5	15.2	7.2
March	35.8	30.8	16.9	8.2
April	34.2	29.7	16.4	8.5
May	32.8	30.9	17.0	9.2
June	35.4	30.5	16.3	9.1
July	36.7	31.7	16.9	9.3
August	36.5	31.9	16.9	8.8
September	35.6	30.9	15.4	10.1
October	35.9	32.0	26.0	8.8
November	34.3	30.9	13.7	8.2
December	35.3	32.0	14.1	8.6

TABLE 10: Monthly volume publication trend for Sentinel-3 per product source (e.g. sensor) in 2023 (in TB).

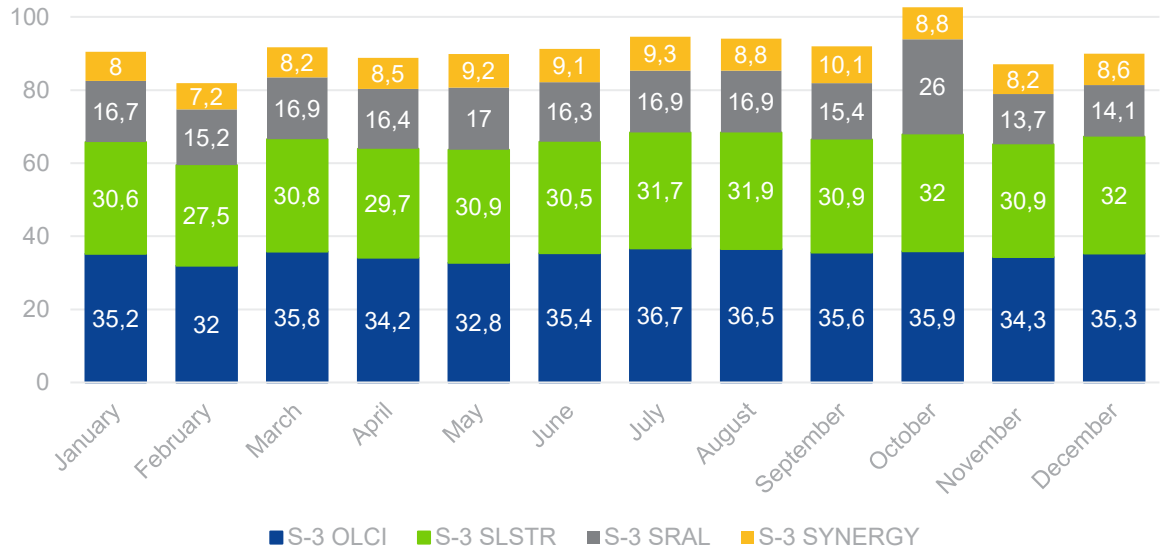


FIGURE 21: Monthly volume publication trend per Sentinel-3 user-level data source (e.g. sensor) in 2023 (in TB).

Sentinel-5P:

Sentinel-5P produces approximately 100,000 products per month, and this amount was published monthly for most of 2023. The main deviations occurred in March and April, when larger data portions, both in terms of the number of products and their volume, were added to the CDSE to complete the archive in terms of space and time. Figure 22 illustrates the distribution of data published throughout the year.

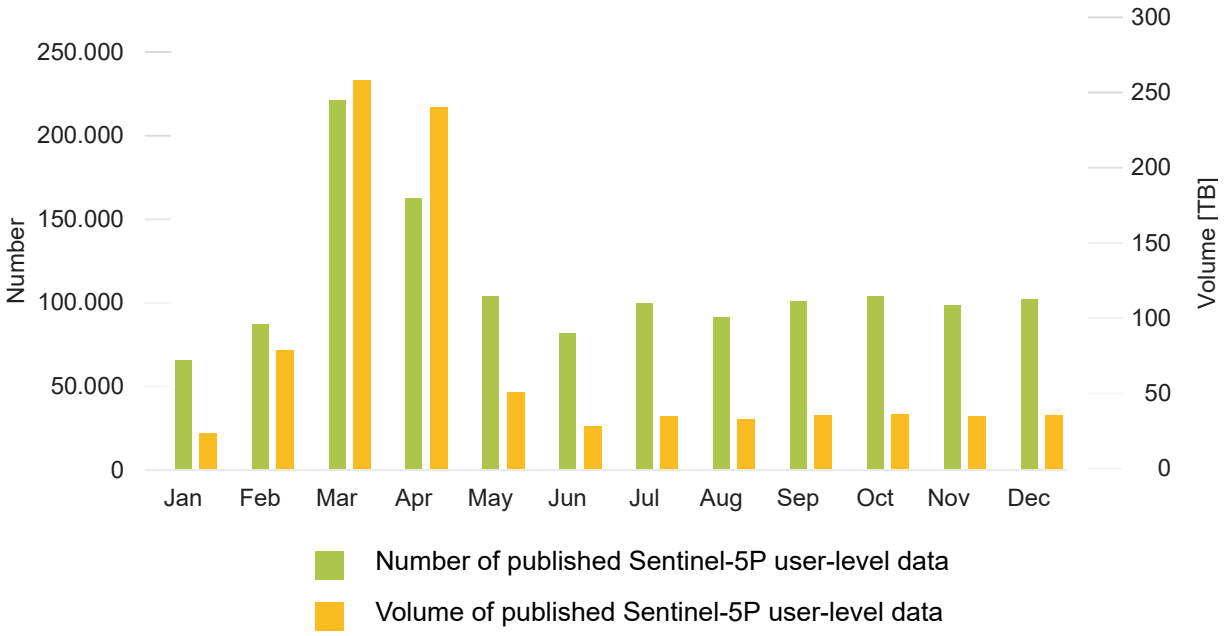


FIGURE 22: Monthly number and volume publication trend for Sentinel-5P in 2023.

Table 11 provides a summary of the published products for each mission, categorized by product type. It presents both the quantity and volume of each product type, along with their respective proportions of the total number and size for each mission. Figures 23 and 24 visually represent this data for number and volume, respectively, facilitating easy comparison across missions and product types.

Mission	Type	Count	% of total count	Volume [TB]	% of total volume
S1	AUX	81,349	2%	6.8	0.1%
	GRDH	2,668,876	68%	2,919.35	58%
	GRDM	597,658	15%	157.85	3%
	OCN	130,464	3%	2.70	0.1%
	RAW	226,705	6%	339.31	7%
	SLC	214,451	5%	1,602.59	32%
	S1 Total	**3,919,503**		**5,028.60**	
S2	AUX	1,700	0.0%	0.00	0.0%
	L1C	14,438,510	42%	7,148.53	35%
	L2A	19,877,248	58%	13,120.22	65%
	S2 Total	**34,317,458**		**20,268.75**	
S3	AUX	3,681	0.1%	0.03	0.0%
	OLCI	1,031,460	21%	419.67	38%
	SLSTR	2,545,938	52%	369.46	34%
	SRAL	940,105	19%	200.88	18%
	SYNERGY	373,595	8%	102.53	9%
	S3 Total	**4,894,779**		**1,092.57**	
S5P	AUX	3,438	0.3%	6.35	0.7%
	L1B	499,613	38%	741.95	83%
	L2	814,156	62%	141.35	16%
	S5P Total	**1,317,207**		**889.66**	
ALL		**44,448,947**		**27,279.59**	

TABLE 11: Percentage published number and volume of user-level data per Sentinel mission and data type during 2023.

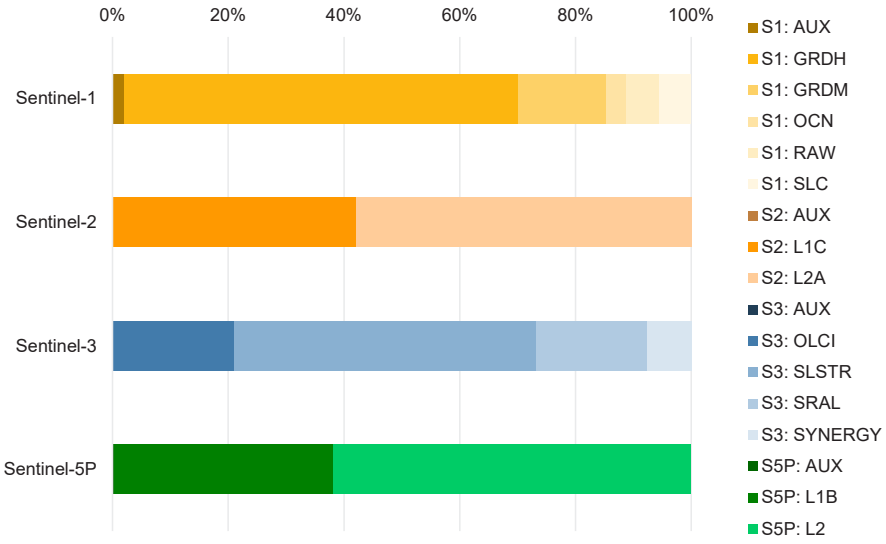


FIGURE 23: Percentage published number of user-level data per Sentinel mission and user-level data type during 2023.

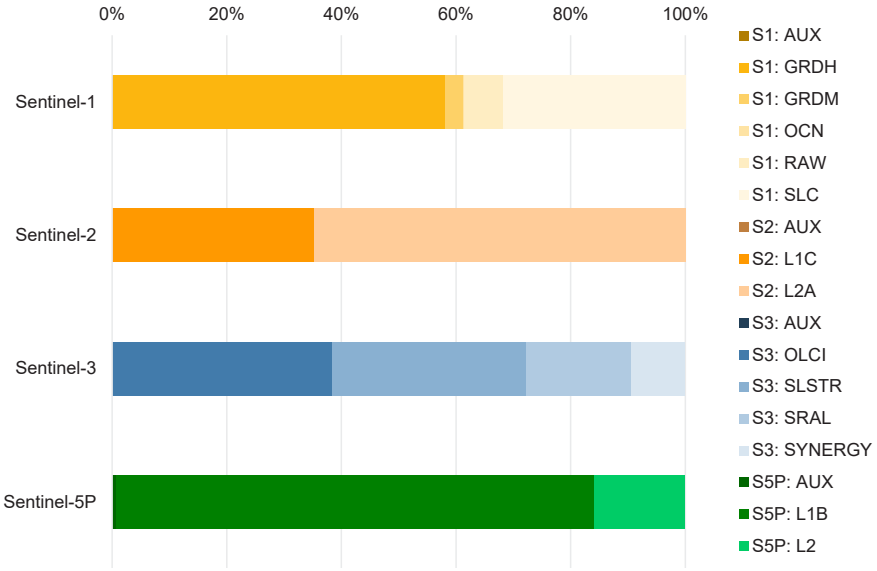


FIGURE 24: Percentage published volume of user-level data per Sentinel mission and user-level data type during 2023.

5.2 Publication per Geographical coverage:

The Sentinel observation scenarios generally follow the pre-defined Sentinel High Level Observation Plan (HLOP) which is aimed at delivering the observation requirements for the Copernicus services. The Sentinel HLOP can be assessed here:

Sentinel High Level Operations Plan (HLOP)

Consequently, the geographical areas covered by specific Sentinel missions are defined by their individual observation scenarios, which can be found online through the following links:

Sentinel-1:
- https://sentiwiki.copernicus.eu/web/s1-mission
- https://sentinels.copernicus.eu/web/sentinel/copernicus/sentinel-1/observation-scenario

Sentinel-2:
- https://sentiwiki.copernicus.eu/web/s2-mission

Sentinel-3:
- https://sentiwiki.copernicus.eu/web/s3-mission

Sentinel-5P:
- https://sentiwiki.copernicus.eu/web/s5p-mission

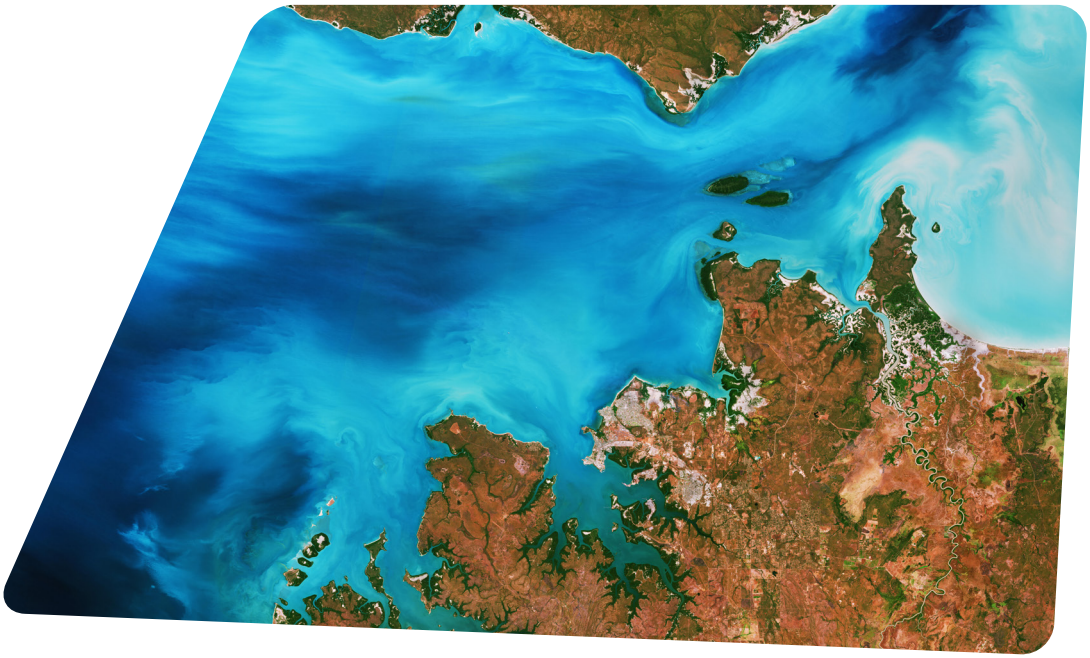


Image source: *esa.int, Clarence Strait Australia, modified Copernicus Sentinel data, ESA standard licence*

5.3 Heatmaps:

The Heatmaps presented below illustrate the geographical distribution of the number of published products from the start of operations until end of 2023. In all heatmaps, white indicates areas for which no data was published.

Sentinel-1

Figure 25 presents a geographical coverage heatmap of Sentinel-1 user-level data published from the start of Sentinel-1 operations until the end of 2023. The colour scale shows the varying quantities of user-level data published for different areas on the globe. Dark red fields represent regions with the highest numbers of published Sentinel-1 user-level data. This heatmap includes all user-level data type except for OCN.

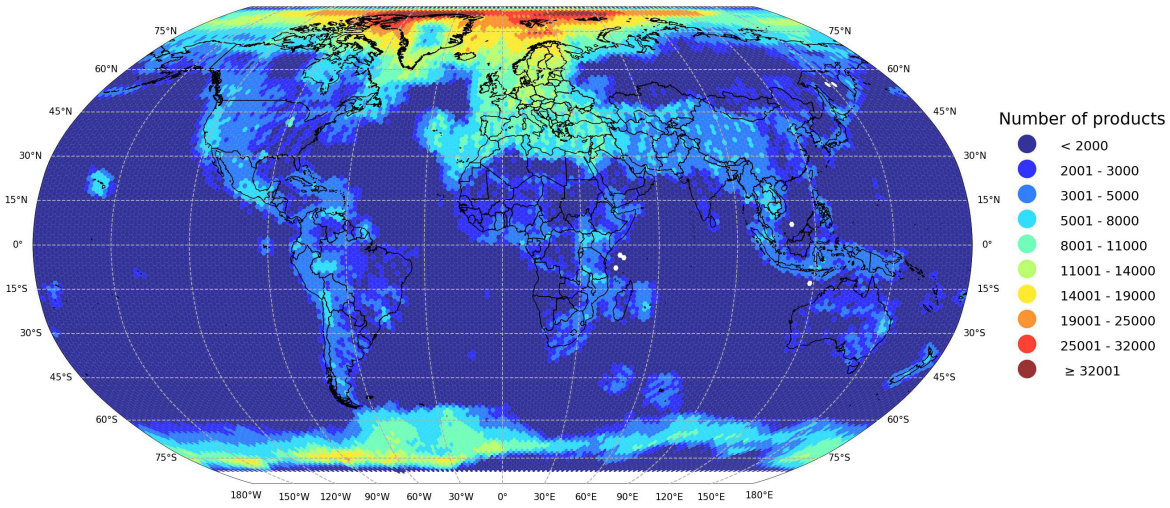


FIGURE 25: Heatmap of Sentinel-1 user-level data (excluding OCN) published from the start of operations to the end of 2023. White colour indicates areas where no data was published.

To facilitate a more detailed analysis on Sentinel-1 user-level data, the following heatmaps show GRDM (Figure 26), GRDH (Figure 27), and SLC (Figure 28) individually.
The Sentinel-1 GRDM (Ground Range Detected Medium Resolution) user-level data type is designed to capture medium resolution radar imagery, with a focus on sea, ice, and polar marine areas.

The Sentinel-1 GRDH (Ground Range Detected High Resolution) user-level data type provides high-resolution radar imagery primarily focused on land areas. This data type is mainly associated with the Interferometric Wide Swath (IW) mode and offers a detailed view of terrestrial features and changes over time.

The Sentinel-1 SLC (Single Look Complex) user-level data type provides radar imagery with a high level of detail and phase information. This data type is primarily associated with the Interferometric Wide Swath (IW) mode and the Stripmap (SM) mode, offering both wide coverage and detailed imaging capabilities.

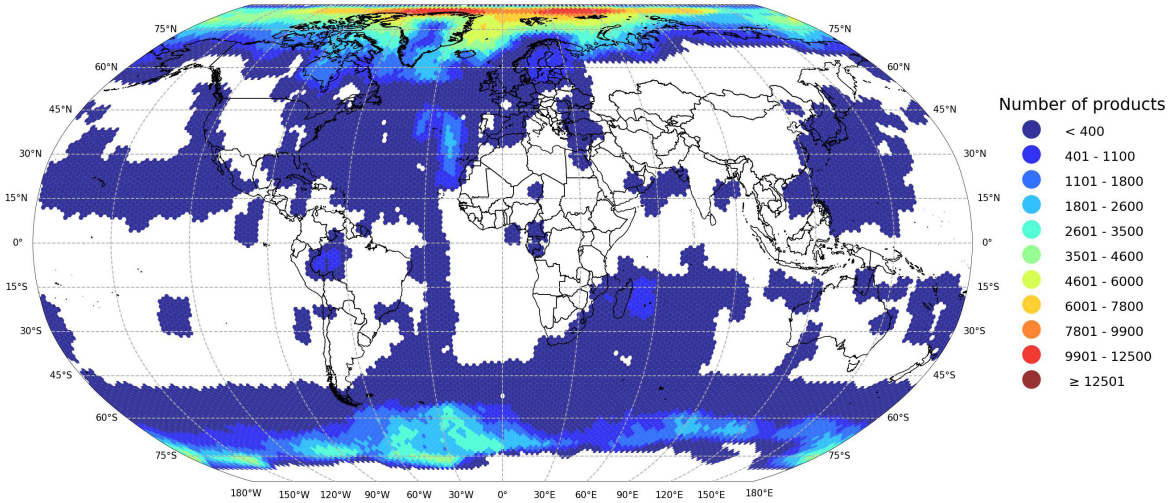


FIGURE 26: Heatmap of Sentinel-1 GRDM user-level data published from the start of operations to the end of 2023. White colour indicates areas where no data was published.

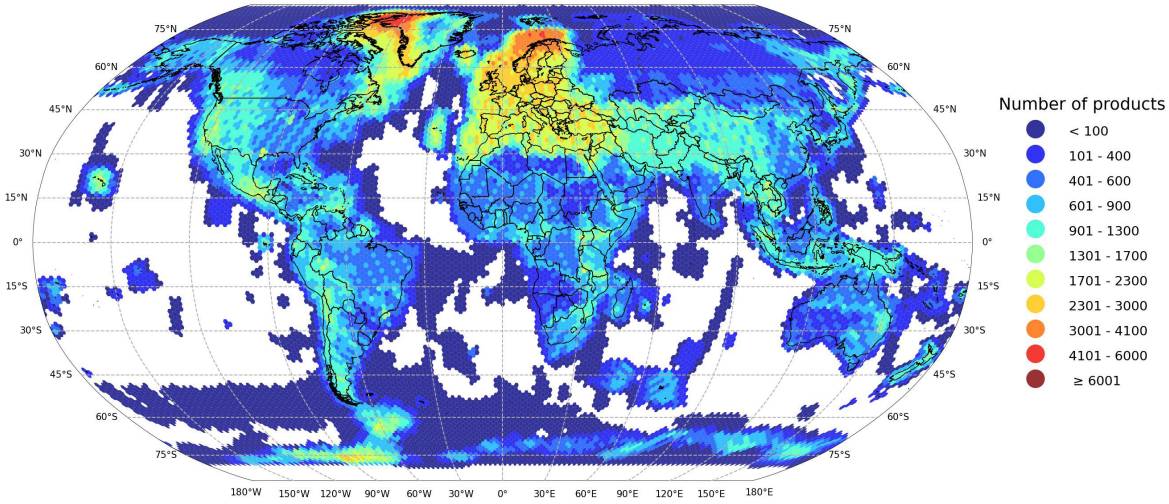


FIGURE 27: Heatmap of Sentinel-1 GRDH user-level data published from the start of operations to the end of 2023. White colour indicates areas where no data was published.

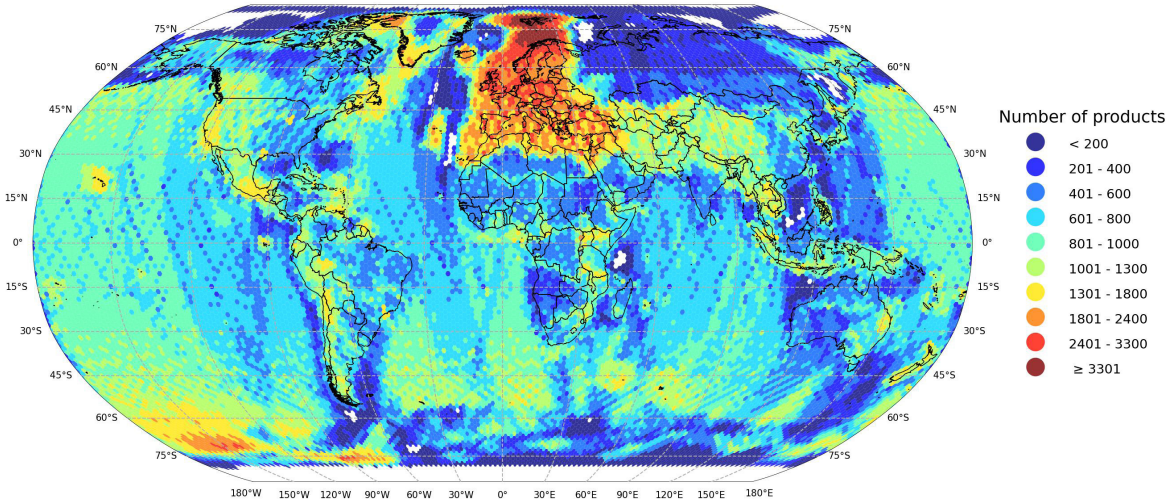


FIGURE 28: Heatmap of Sentinel-1 SLC user-level data published from the start of operations to the end of 2023. White colour indicates areas where no data was published.

Sentinel-2

Figure 29 and Figure 30 present geographical coverage heatmaps of Sentinel-2 user-level data published from the start of Sentinel-2 operations until the end of 2023, for Level-1C and Level-2A, respectively. Please note that maps include standard user-level data only, i.e. without the reprocessed data.

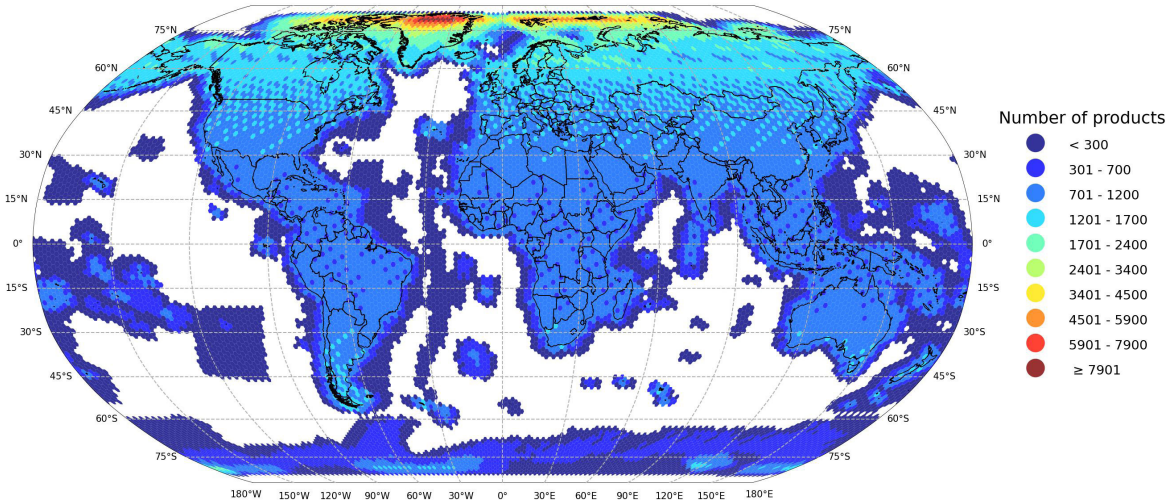


FIGURE 29: Heatmap of Sentinel-2 Level-1C user-level data published from the start of operations to the end of 2023. White colour indicates areas where no data was published.

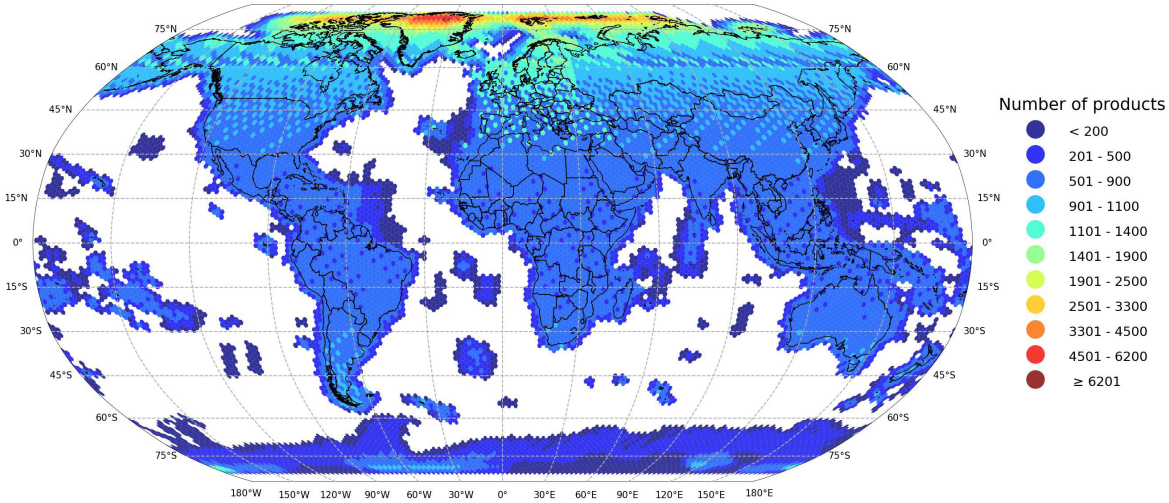


FIGURE 30: Heatmap of Sentinel-2 Level-2A user-level data published from the start of operations to the end of 2023. White colour indicates areas where no data was published.

Sentinel-3

The following heatmaps present the geographical coverage for Sentinel-3 user-level data from the start of operations until 2023. The heatmaps, provided in Figures 31-35 correspond to five data groups: SRAL (excluding NRT and Level-2), SRAL-NRT Level-2, OLCI, SLSTR, and SYNERGY.

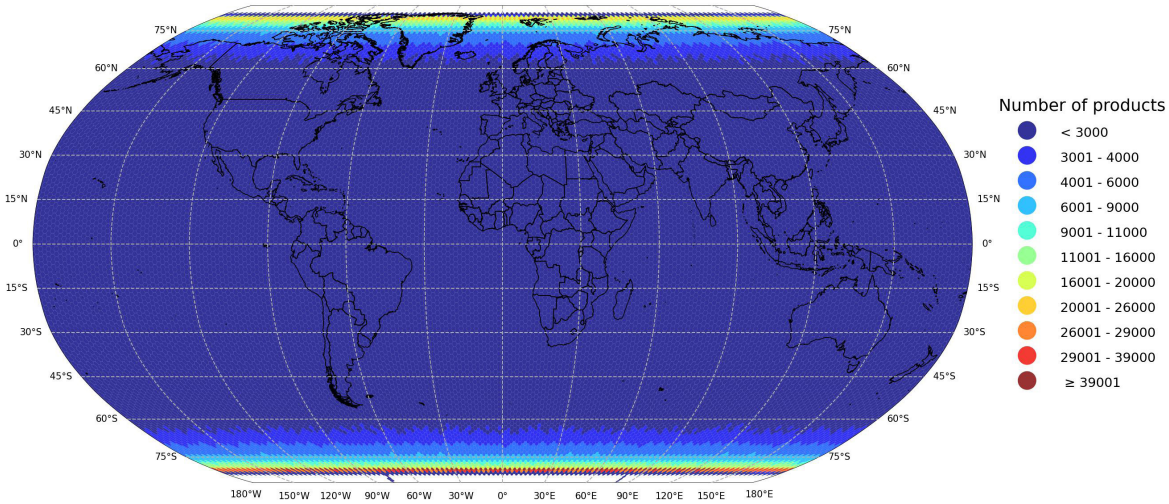


FIGURE 31: Heatmap of Sentinel-3 SRAL (excluding NRT and Level-2) user-level data published from the start of operations to the end of 2023. White colour indicates areas where no data was published.

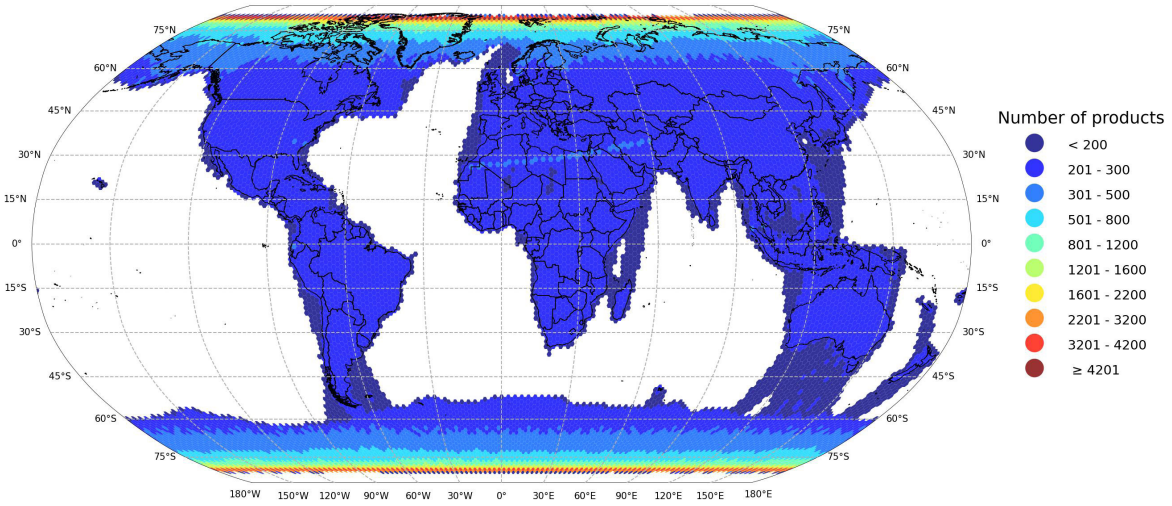


FIGURE 32: Heatmap of Sentinel-3 SRAL-NRT Level-2 user-level data published from the start of operations to the end of 2023. White colour indicates areas where no data was published.

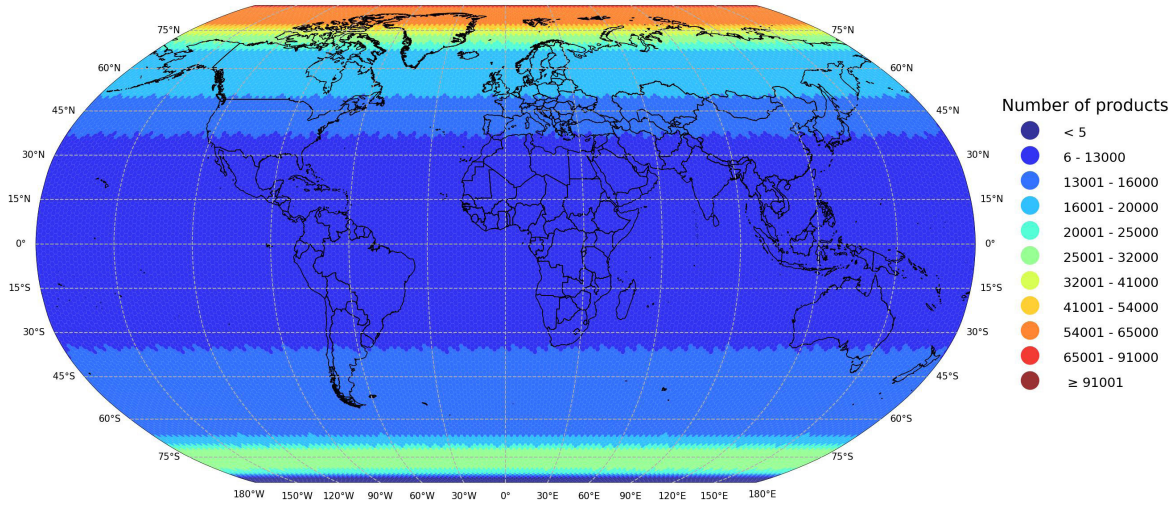


FIGURE 33: Heatmap of Sentinel-3 OLCI user-level data published from the start of operations to the end of 2023..

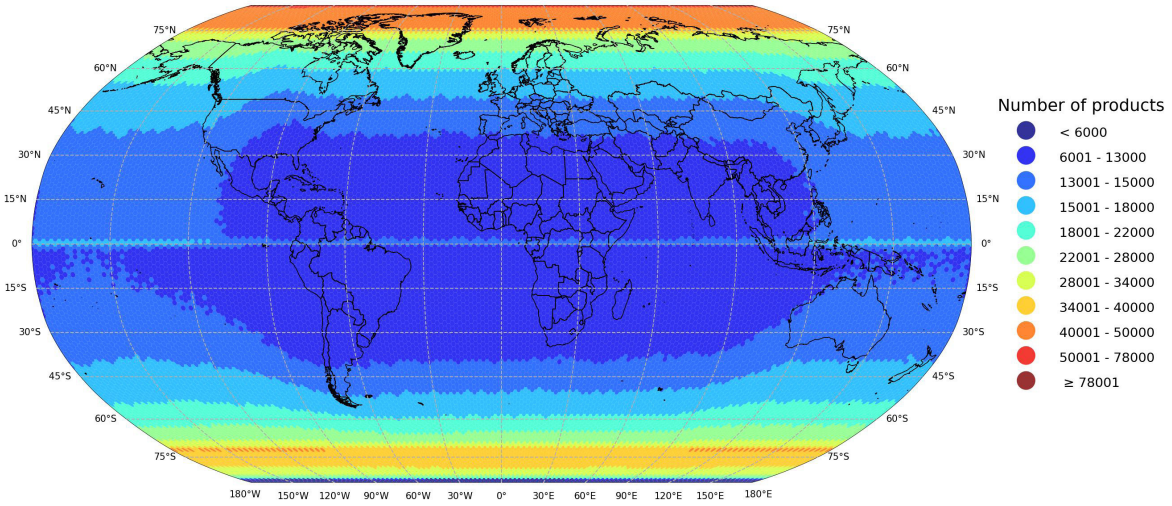


FIGURE 34: Heatmap of Sentinel-3 SLSTR user-level data published from the start of operations to the end of 2023.

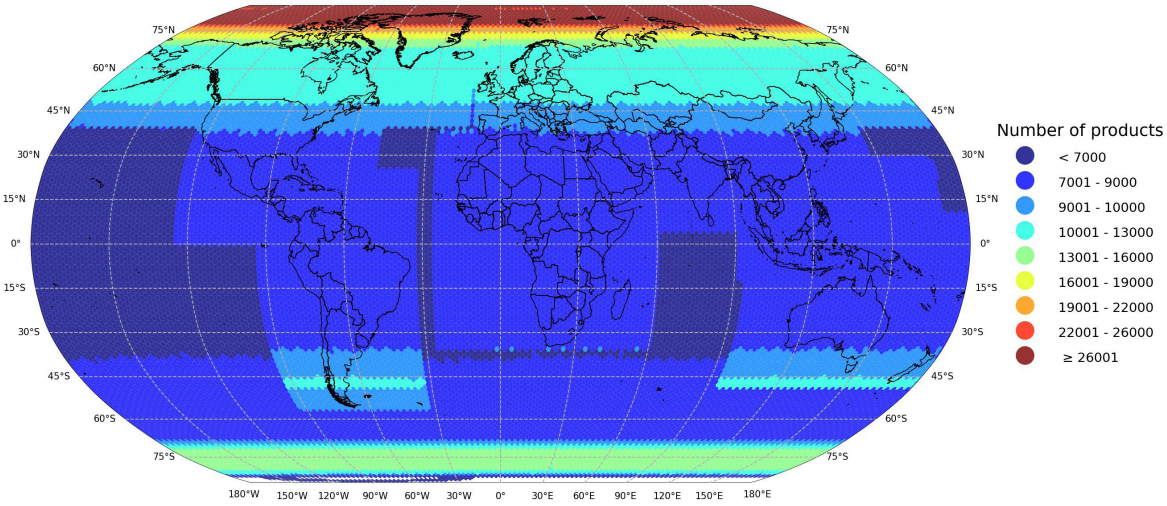


FIGURE 35: Heatmap of Sentinel-3 SYNERGY user-level data published from the start of operations to the end of 2023. White colour indicates areas where no data was published.

Sentinel-5P

Figure 36 presents the Sentinel-5P user-level data (Level-1 and Level-2, NRT and NTC) published from the beginning of operations until the end of 2023. This data is uniformly collected from across the globe, so the increase in the number of products with latitude is solely due to the overlap of the field of view from individual orbits.

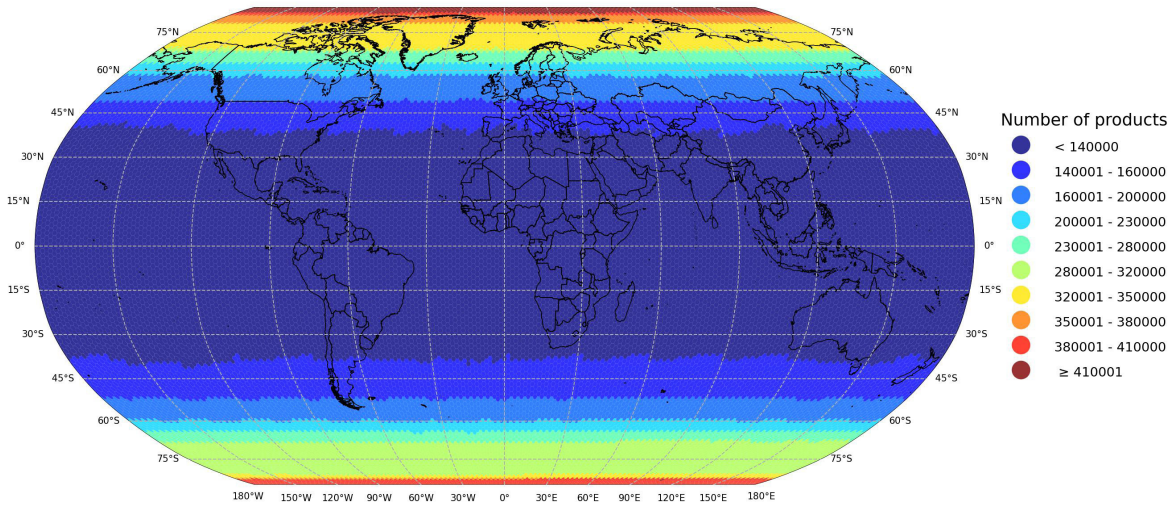


FIGURE 36: Heatmap of Sentinel-5P user-level data (Level-1 and Level-2, NRT and NTC) published from the start of operations to the end of 2023.

Image source: *copernicus.eu, Image of the Day, 2023/08/15 Etna Eruption, Sicily*

6 DATA DELIVERY

As presented in the previous chapter, the quantity of Sentinel user-level data made available for download on the CDSE increased considerably, reaching nearly 94 million products. In this section, we provide statistics on data delivery in 2023, focusing on how users accessed the data available in the CDSE. It is important to note that users accessed the data via numerous interfaces, with actual downloads constituting only a fraction of data delivered from the EO repository to applications and the cloud. There are 4 main streams via which data was made available:

- data download
- data access via Sentinel Hub
- data access via OpenE0
- data access from federated cloud environments

Since this is the first report produced for the CDSE, the only data download statistics for 2022 to be used for comparison are those reported in the Sentinel Data Access Service Annual Report 2022. However, because the collection of statistics for CDSE download started in July 2023 and the Sentinel Data Access Service statistics for 2022 cover the period 1.1 – 31.12.2022, comparing the CDSE data download volumes to the volumes recorded for 2022 is challenging. Nevertheless, if the December 2023 CDSE download volume of 5.9 PB (see Table 12) is compared to the average monthly downloads recorded for the previous years (6.9 PB in 2020, 6.7 PB in 2021, and 6.8 PB in 2022) as reported in the 2022 Copernicus Sentinel Data Access Annual Report (see Figure 37 therein), it appears that download volumes have remained stable over the past few years.

However, Section 6.2 describes a significant increase in streamlined services during the CDSE operations, and this suggests that users have enthusiastically adopted the options for discovering and analyzing the data in the browser and through the services rather than by downloading it, and even that they now prefer to engage with the data in this way. In December 2023, over 30 PB of data were delivered by the EO repository to the cloud environment, with almost 6 PB of direct downloads to users, 15 PB to users in federated clouds, 10 PB through streamlined data access interfaces, and the rest for technical tasks such as traceability, mosaic generation, reprocessing, and others.

6.1. Data download

In this section, we present the number and size of downloaded products. Data delivered through other streams (e.g., streamlined data access, cloud data access) is not reflected in the statistics of this section.

All download statistics in this report consider only OData/Zipper interface, and encompass all user roles combined.

6.1.1. Data download summary

The Table 12 below presents the number and volume of data downloads made for Sentinel mission, in the period from July to December 2023. Based on the same data, Figure 37 illustrates the counts as a bar plot, and shows the percentage of downloads for each mission.

The findings can be summarised as follows:

- **Sentinel-1:** A total of 4,387 TB was downloaded, accounting for 23% of the total volume of data downloaded across all missions. The number of downloads for Sentinel-1 was 3,544,355, which represents 7% of the number of all downloads.
- **Sentinel-2:** This mission saw the highest volume of downloads with 12,693 TB, making up 66% of the total download volume. There were 39,227,119 downloads of Sentinel-2 products, which is 77% of the total number of downloads, making it by far the most frequently accessed mission.
- **Sentinel-3:** Downloads for this mission totalled 1,508 TB (8% of the total download volume). The count of downloads was 6,056,907, or 12% of the total number of downloads.
- **Sentinel-5P:** This mission had 686 TB of data downloaded (4% of total download volume) and 1,960,830 downloads (4% of total number of downloads).

The total volume of data downloaded across all missions was 19,275 TB, with a total number of 50,789,211 downloads. The data indicates that Sentinel-2 is the most utilized in terms of both the volume of data downloaded and the number of individual downloads.

Mission	TB	% of Total	Count	% of Total
Sentinel-1	4,387	23%	3,544,528	7%
Sentinel-2	12,693	66%	39,227,119	77%
Sentinel-3	1,508	8%	6,056,907	12%
Sentinel-5P	686	4%	1,960,830	4%
Grand Total	**19,275**		**50,789,211**	

TABLE 12: Total volume and number of user-level data downloads per mission using OData/Zipper interface from July to December 2023.

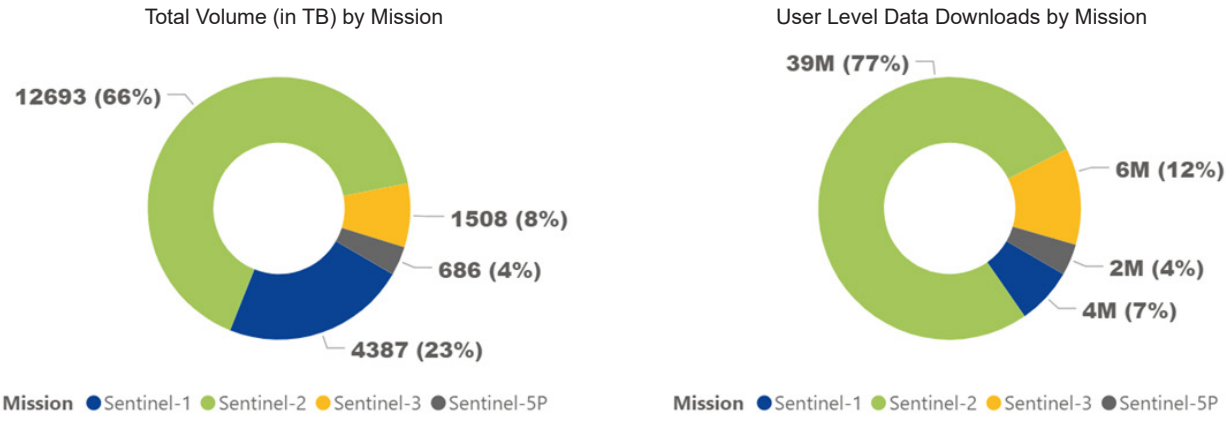


FIGURE 37: Total volume and number of user-level data downloads per mission using OData/Zipper interface from July to December 2023.

6.1.2. Volume Exploitation Ratio (VER)

The Volume Exploitation Ratio (VER) is another method for tracking the demand for Sentinel user-level data by dividing the volume of downloaded products by the volume of published products. Using this calculation, it is possible to generate heatmaps, which give an indication of the geographical areas for which there was the most interest from users. The heatmaps below provide a detailed view on each Sentinel mission, broken down by instrument, data level, and timeliness.

It is important to note that VER computed by CDSE is not directly comparable with the Archive Exploitation Ratio (AER) measure which was previously used in the 2022 Copernicus Sentinel Data Access Annual Report. There are three reasons for this:

- data downloads have been measured in CDSE from July until the end of 2023, not for the whole year as in 2022.
- VER heatmaps were calculated based on a fraction of data downloads provided by the Zipper interface alone, as statistics of data retrieved by other interfaces are not available for 2023.
- AER is based on number of downloads, while the current method (VER) is based on the volume of downloads. VER takes into account partial downloads (i.e. when part of a data package is retrieved by a user), whereas AER, based on a ratio of the number of data downloaded and published, did not account for this.

It is also worth noting that the presented maps only represent the interest of users who downloaded data.The heatmaps do not contain the statistics for the data which was processed with the built-in CDSE tools and through the federated cloud interfaces. It is suggested that this is the reason there appears to be relatively low usage of data covering Europe, as those data were more often processed with other available interfaces.

In all heatmaps, the colour white is not presented in the legend, but the white areas indicate a lack of data. This lack of data could be due to either no published products in a particular area or zero downloads of those products.

Sentinel-1

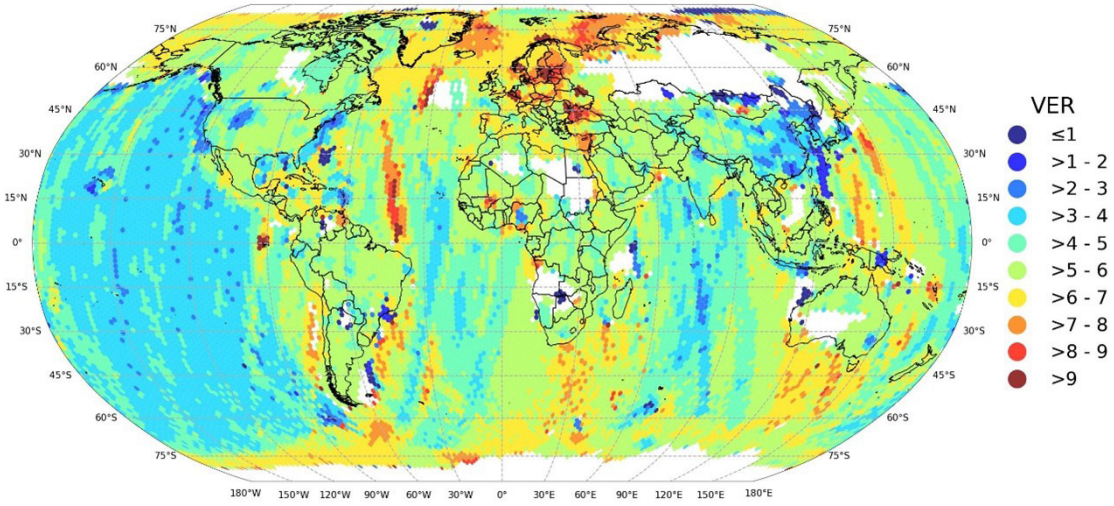


FIGURE 38: Heatmap of the Volume Exploitation Ratio for Sentinel-1 (excluding OCN) user-level data during July-December 2023 (using OData/Zipper interface). White color indicates areas where no data was published or downloaded.

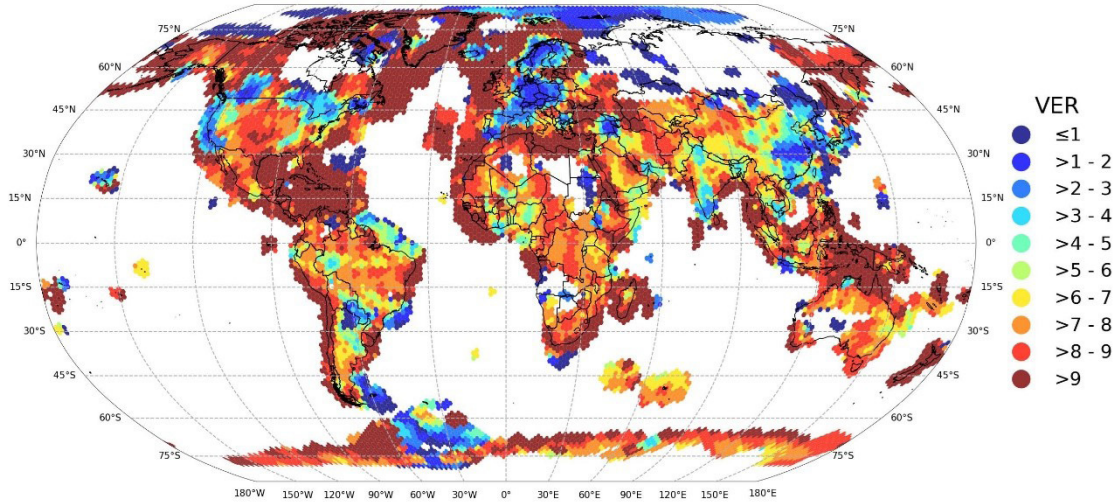


FIGURE 39: Heatmap of the Volume Exploitation Ratio for Sentinel-1 GRDH user-level data during July-December2023 (using OData/Zipper interface). White color indicates areas where no data was published or downloaded.

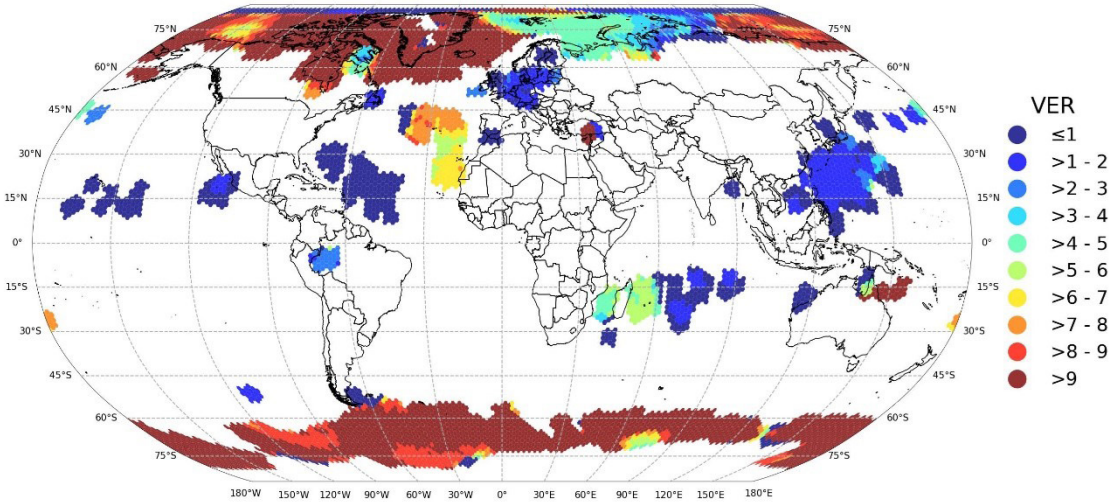


FIGURE 40: Heatmap of the Volume Exploitation Ratio for Sentinel-1 GRDM user-level data during July-December 2023 (using OData/Zipper interface). White color indicates areas where no data was published or downloaded.

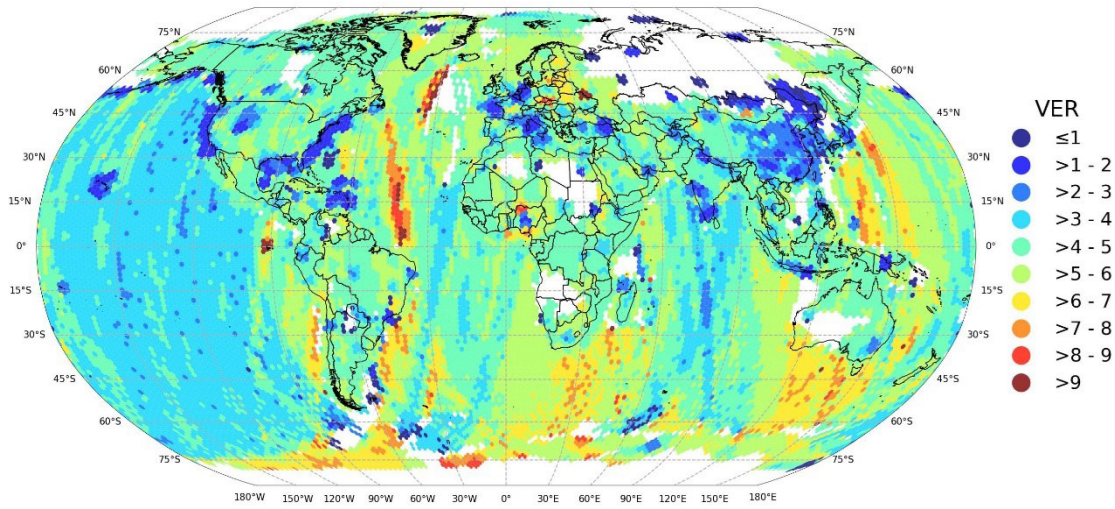


FIGURE 41: Heatmap of the Volume Exploitation Ratio for Sentinel-1 SLC user-level data during July-December2023 (using OData/Zipper interface). White color indicates areas where no data was published or downloaded.

Sentinel-2

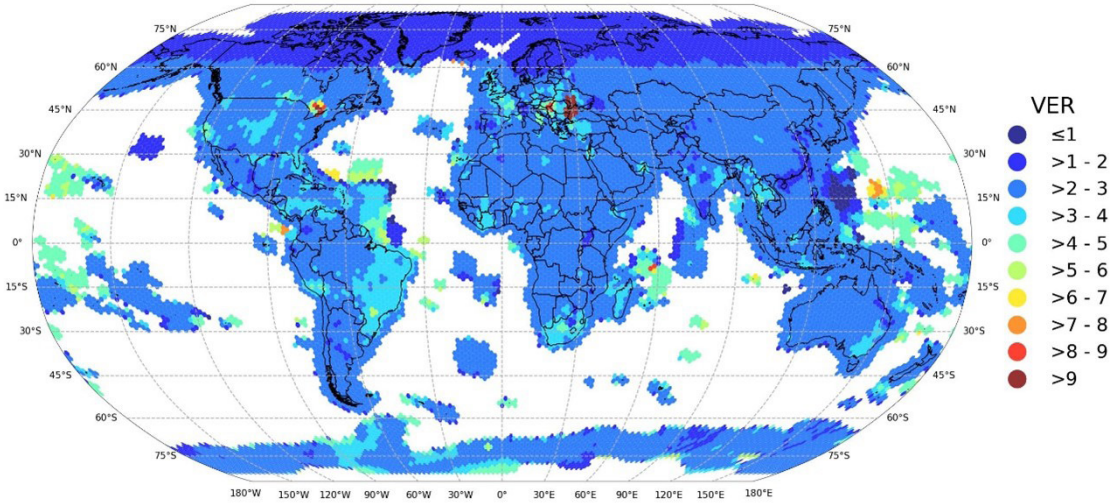


FIGURE 42: Heatmap of the Volume Exploitation Ratio for Sentinel-2 Level-1C user-level data during July-December2023 (using OData/Zipper interface). White color indicates areas where no data was published or downloaded.

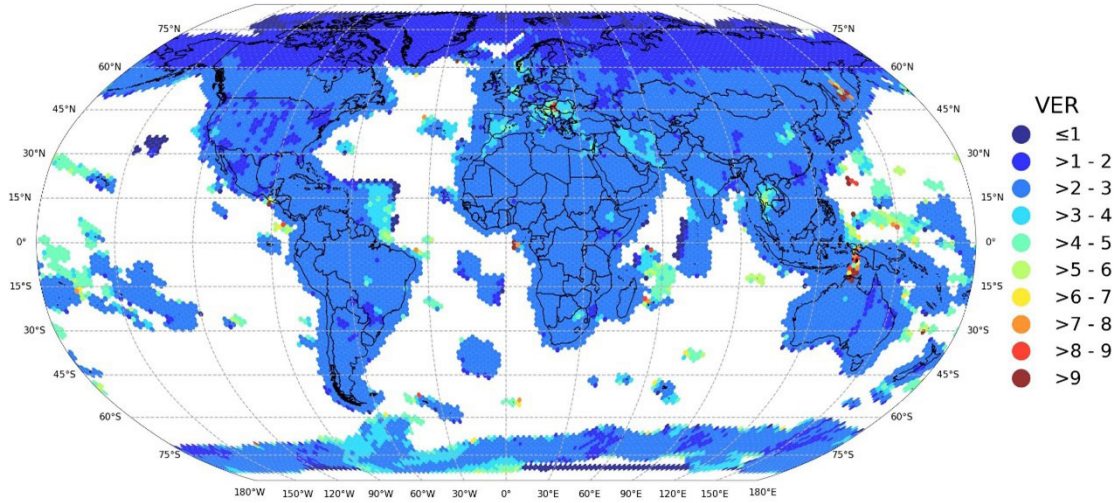


FIGURE 43: Heatmap of the Volume Exploitation Ratio for Sentinel-2 Level-2A user-level data during July-December2023 (using OData/Zipper interface). White color indicates areas where no data was published or downloaded.

Sentinel-3

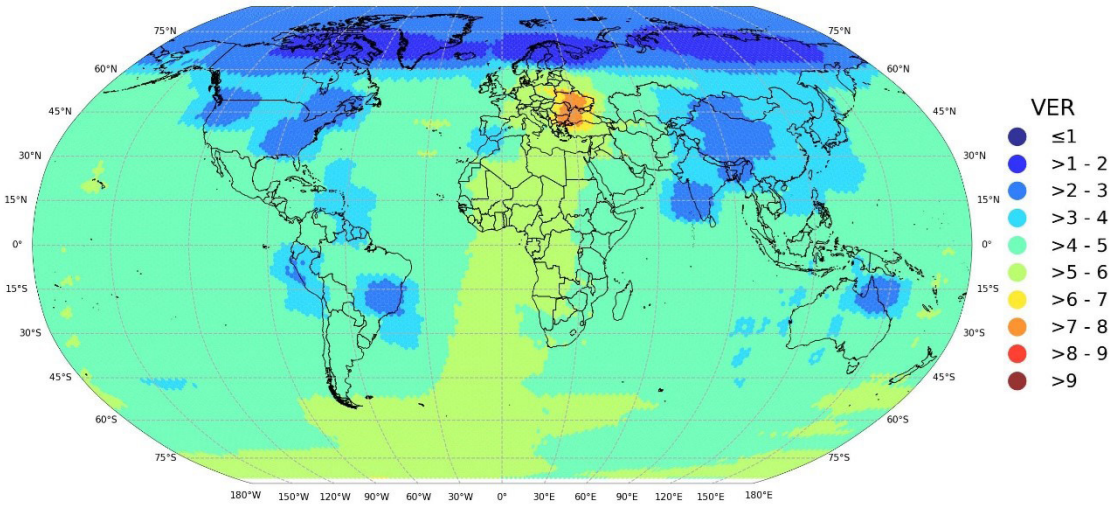


FIGURE 44: Heatmap of the Volume Exploitation Ratio for Sentinel-3 OLCI user-level data during July-December2023 (using OData/Zipper interface) . White color indicates areas where no data was published or downloaded.

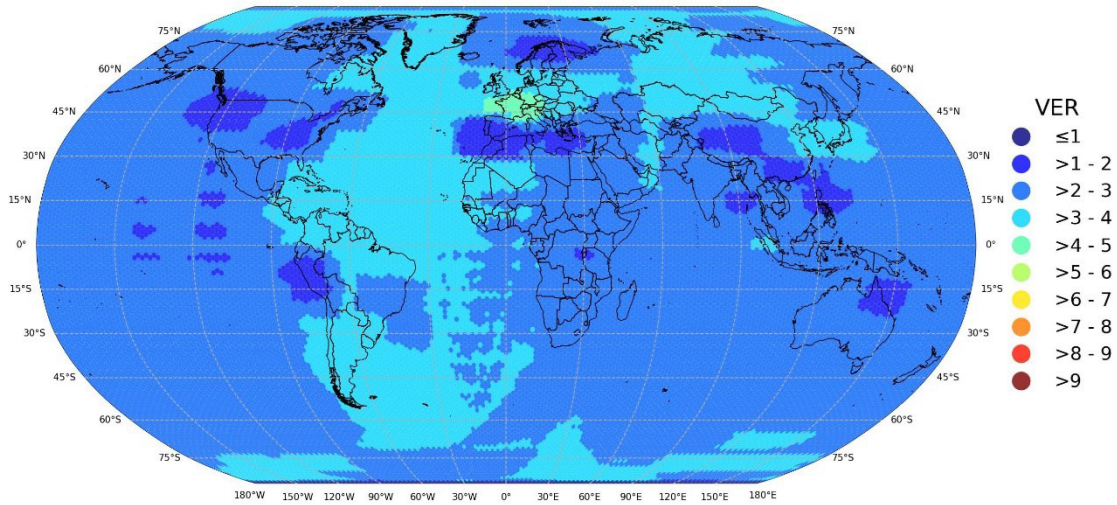


FIGURE 45: Heatmap of the Volume Exploitation Ratio for Sentinel-3 SLSTR user-level data during July-December2023 (using OData/Zipper interface) . White color indicates areas where no data was published or downloaded.

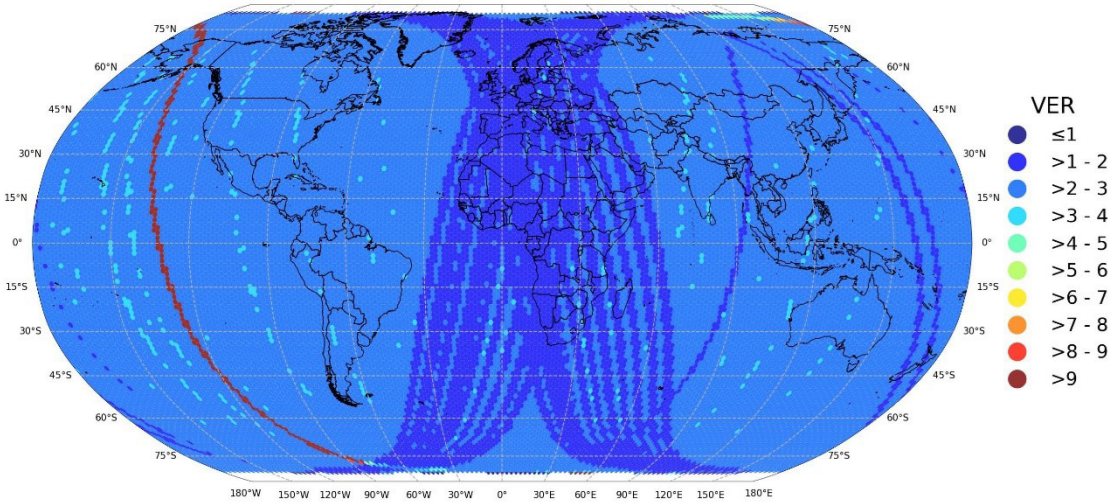


FIGURE 46: Heatmap of the Volume Exploitation Ratio for Sentinel-3 SRAL (excluding NRT and Level-2) user-level data during July-December 2023 (using OData/Zipper interface) . White color indicates areas where no data was published or downloaded.

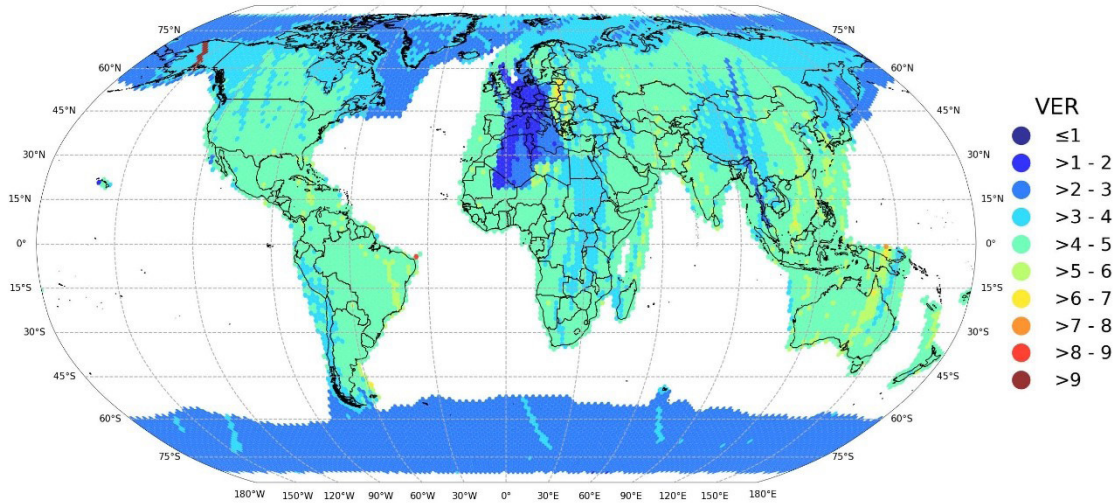


FIGURE 47: Heatmap of the Volume Exploitation Ratio for Sentinel-3 SRAL-NRT Level-2 user-level data during July-December 2023 (using OData/Zipper interface) . White color indicates areas where no data was published or downloaded.

Sentinel-5P

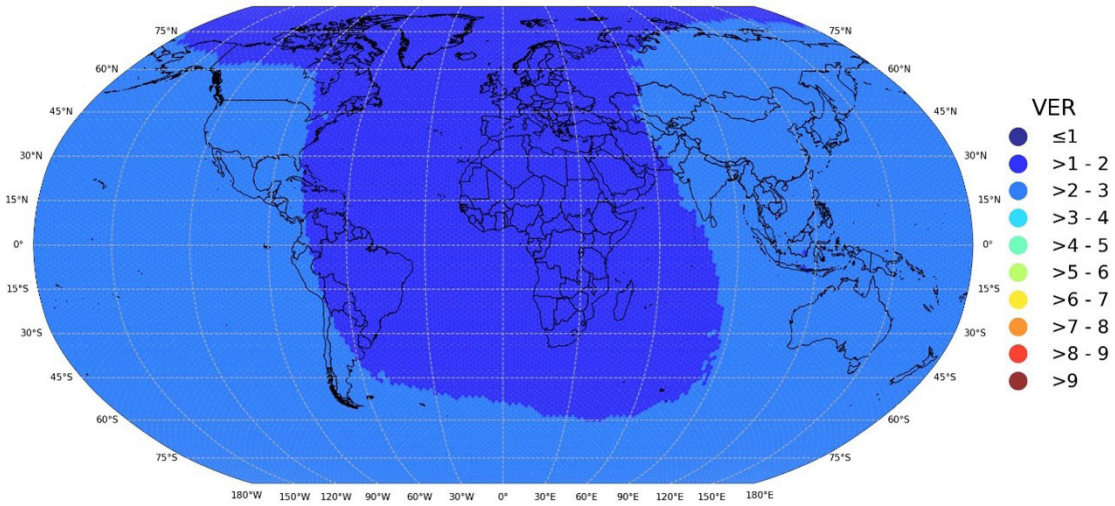


FIGURE 48: Heatmap of the Volume Exploitation Ratio for Sentinel-5P user-level data during July-December2023 (using OData/Zipper interface). White color indicates areas where no data was published or downloaded.

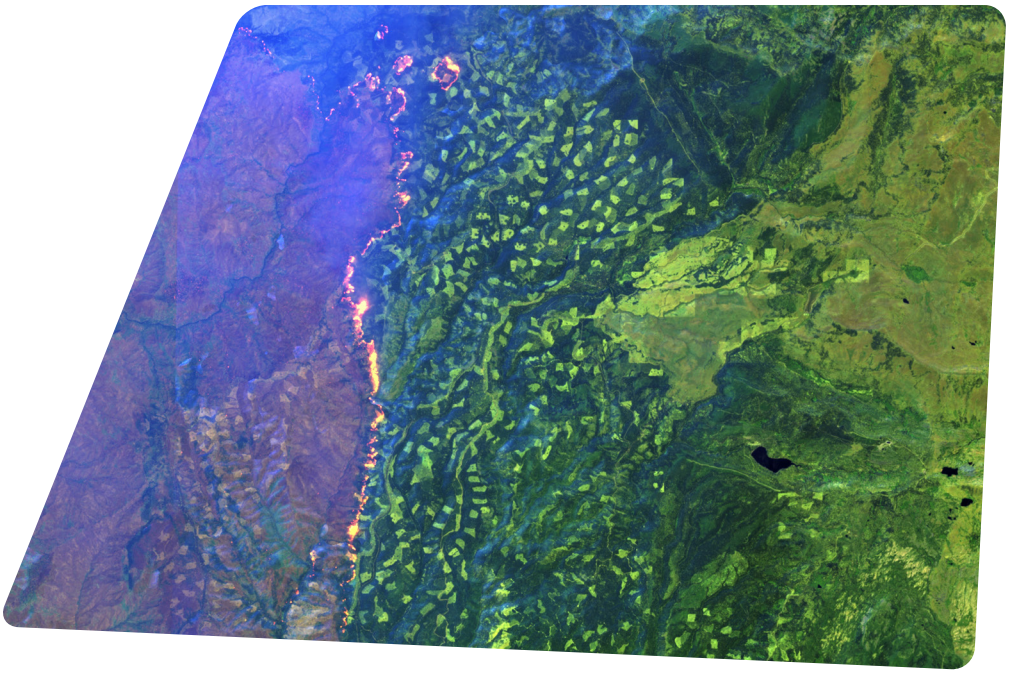


Image source: *copernicus.eu, Image of the Day, 2024/07/27 California, contains modified Copernicus Sentinel-2 data*

6.1.3. Data download per collection and type

Table 13 presents the number of user-level data types downloaded for each mission. It shows that the most downloaded data types per mission (in terms of count) were: GRD for Sentinel-1, L1C for Sentinel-2, SLSTR for Sentinel-3, and L2 for Sentinel-5P.

Table 14 presents the split of downloaded Sentinel-2 data into standard and reprocessed data. It is clear that reprocessed data (Sentinel Collection 1) of L2A constituted more than half of all L2A downloads. Figures 49 and 50 show the shares of each product type within the Sentinel-1 and Sentinel-2 missions, respectively.

Collection	Type	Count	% of total
Sentinel-1	AUX	1,657,259	3,3%
	GRD	883,314	1,7%
	OCN	397,074	0,8%
	SLC	357,384	0,7%
	RAW	248,139	0,5%
	ETA	802	0,0%
	CARD	382	0,0%
	OBS	1	0,0%
	S1 Total	**3,544,528**	**7,0%**
Sentinel-2	L1C	27,097,493	53,4%
	L2A	12,125,599	23,9%
	AUX	4,027	0,0%
	S2 Total	**39,227,119**	**77,2%**
Sentinel-3	SLSTR	3,007,880	5,9%
	OLCI	1,433,755	2,8%
	SRAL	947,539	1,9%
	SYNERGY	661,622	1,3%
	AUX	6,111	0,0%
	S3 Total	**6,056,907**	**11,9%**
Sentinel-5P	L2	1,492,006	2,9%
	L1B	466,315	0,9%
	AUX	2,509	0,0%
	S5P Total	**1,960,830**	**3,9%**
Grand Total		**50,789,384**	

TABLE 13: Number and percentage of Sentinel user-level data types downloaded per type, using the OData/Zipper interface, between July-December 2023.

Collection	Type	All products	Re-processed	% of reprocessed products downloads
Sentinel-1	L1C	27,097,493	2,114,623	7,80%
Sentinel-2	L2A	12,125,599	6,225,588	51,34%

TABLE 14: Number and percentage of Sentinel-2 reprocessed user-level data downloaded using OData/Zipper interface in 2023 (since July).

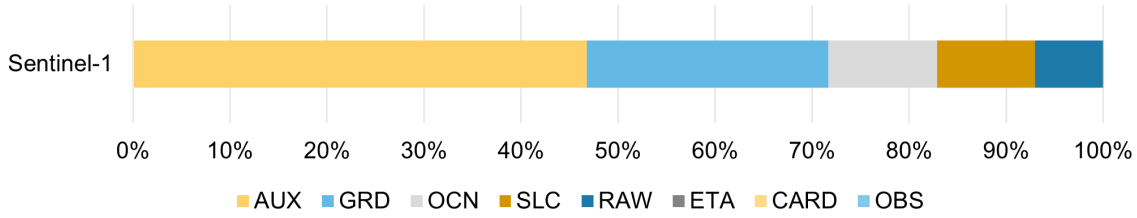


FIGURE 49: Percentage of Sentinel-1 user-level data downloaded per type using OData/Zipper interface in 2023 (since July).

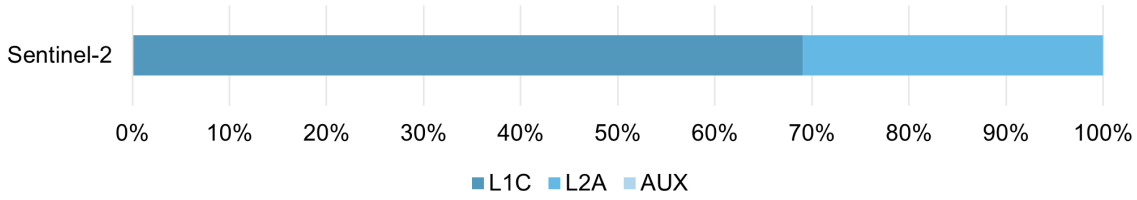


FIGURE 50: Percentage of Sentinel-2 user-level data downloaded per type using OData/Zipper interface in 2023 (since July).

Table 15 illustrates the number of downloaded Sentinel-3 data grouped by all product types. Almost half of the downloads were related to SLSTR-based products, with the Fire Radiative Power (SL_2_FPR) product accounting for 22% of all Sentinel-3 downloads. For the OLCI sensor, the majority of downloads were radiances (OL_1_EFR) and Level-2 geophysical parameters (OL_2_LFR), both in full spatial resolution. Level-2 products were also pre-dominantly downloaded for SRAL, specifically C-band parameters over land (SR_2_LAN). Among all products created from a fusion of OLCI and SLSTR sensors (SYNERGY), the most popular were band-specific surface reflectances and aerosol parameters included in SY_2_SYN.

Figure 51 presents the same statistics graphically, showing the share of each sensor in all Sentinel-3 downloads. For SLSTR and SRAL, more than 40% and more than 30% of downloaded data came from reprocessing for SRA and LAN, respectively (Table 16). Figure 52 shows the split of Sentinel-5P data downloads into Level 1 and Level 2.

Table 16 illustrates the number and percentage of Sentinel-3 reprocessed user-level data downloaded using OData/Zipper interface in 2023 (since July).

S3 Instrument	Product type	Count	% of total
SLSTR	SL_2_FRP___	1,336,694	22.07%
	SL_1_RBT___	980,425	16.19%
	SL_2_LST___	685,648	11.32%
	SL_2_WST___	3,731	0.06%
	SL_2_AOD___	1,382	0.02%
	SLSTR Total	**3,007,880**	**49.66%**
OLCI	OL_1_EFR___	782,524	12.92%
	OL_2_LFR___	577,485	9.53%
	OL_1_ERR___	31,758	0.52%
	OL_2_WFR___	21,963	0.36%
	OL_2_LRR___	19,115	0.32%
	OL_2_WRR___	910	0.02%
	OLCI Total	**1,433,755**	**23.67%**
SRAL	SR_2_LAN___	751,962	12.41%
	SR_1_SRA___	122,444	2.02%
	SR_2_WAT___	72,081	1.19%
	SRAL Total	**946,487**	**15.63%**
SYNERGY	SY_2_SYN___	619,652	10.23%
	SY_2_AOD___	21,149	0.35%
	SY_2_VGP___	10,995	0.18%
	SY_2_VG1___	8,024	0.13%
	SY_2_V10___	1,708	0.03%
	SY_1_MISR__	94	0.00%
	SYNERGY Total	**661,622**	**10.92%**
AUX	AUX_GNSSRD	3,270	0.05%
	AUX_POEORB	1,685	0.03%
	AUX_PROQUA	1,025	0.02%
	SR___ROE_AX	986	0.02%
	AUX_MOEORB	106	0.00%
	SR___POE_AX	39	0.00%
	SR___MDO_AX	27	0.00%
	AX___MA1_AX	14	0.00%
	AUX_PRCPTF	10	0.00%
	MW_1_DNB_AX	1	0.00%
	AUX Total	**7,163**	**0.12%**
Grand Total		**6,056,907**	

TABLE 15: Number and percentage of Sentinel-3 user-level data downloaded using OData/Zipper interface during 2023 (since July) per user-level data type.

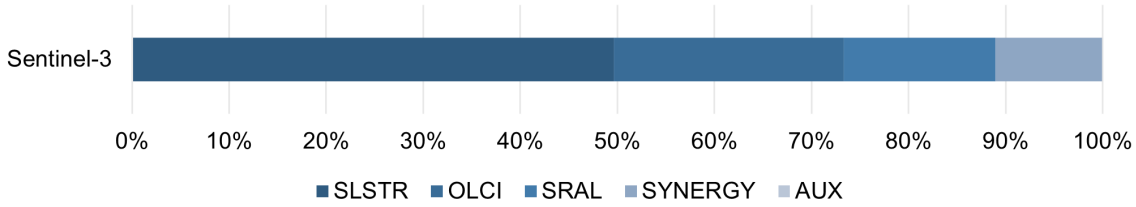


FIGURE 51: Percentage of total number of Sentinel-3 user-level data downloaded using OData/Zipper interface, per group in 2023 (since July).

Collection	Instrument	Type	All products	Reprocessed	% of reprocessed products downloads
Sentinel-3	SRAL	SR_1_SRA___	122,444	50,922	41.59%
Sentinel-3	SRAL	SR_2_LAN___	751,962	246,969	32.84%

TABLE 16: Number and percentage of Sentinel-3 reprocessed user-level data downloaded using OData/Zipper interface in 2023 (since July).

Figure 52 shows that over three-quarters of the Sentinel-5P product downloads were associated with Level-2 products.

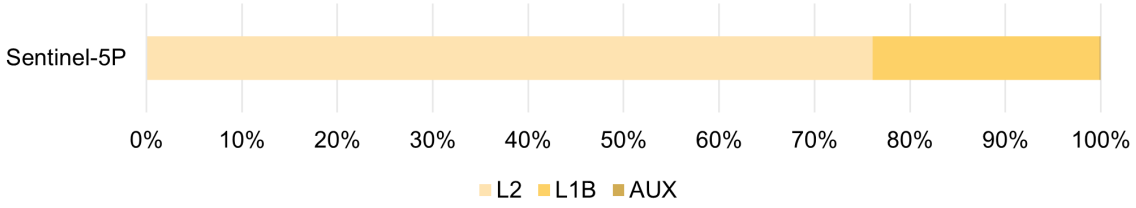


FIGURE 52: Percentage of total number of Sentinel-5P user-level data downloaded using OData/Zipper interface, per type in 2023 (since July).

6.1.4. Data download throughout the year

Table 17 and Figure 53 illustrate the changes in the count and volume of downloaded data over time from July to December 2023. A general trend of increased data downloads each month is evident, except for a drop in August. This increase over time applies to data from all missions, both in terms of the count and volume of downloaded products. In December 2023, nearly 191 TB was downloaded daily, with the majority being Sentinel-2 data, accounting for 94 TB (Table 18).

Month	Collection	Count	TB
Jul-23	Sentinel-1	60,928	127
Jul-23	Sentinel-2	2,783,175	1,797
Jul-23	Sentinel-3	439,347	218
Jul-23	Sentinel-5P	170,987	67
Aug-23	Sentinel-1	88,482	158
Aug-23	Sentinel-2	1,696,706	1,026
Aug-23	Sentinel-3	335,638	66
Aug-23	Sentinel-5P	180,543	63
Sep-23	Sentinel-1	102,405	200
Sep-23	Sentinel-2	2,796,644	1,728
Sep-23	Sentinel-3	237,844	65
Sep-23	Sentinel-5P	214,196	60
Oct-23	Sentinel-1	246,596	666
Oct-23	Sentinel-2	4,453,733	2,654
Oct-23	Sentinel-3	465,924	118
Oct-23	Sentinel-5P	328,445	128
Nov-23	Sentinel-1	891,255	1,049
Nov-23	Sentinel-2	6,665,030	2,591
Nov-23	Sentinel-3	1,914,942	403
Nov-23	Sentinel-5P	466,036	167
Dec-23	Sentinel-1	2,154,862	2,186
Dec-23	Sentinel-2	20,831,831	2,897
Dec-23	Sentinel-3	2,663,212	638
Dec-23	Sentinel-5P	600,623	202

TABLE 17: Dissemination volume trends using OData/Zipper interface, per month and mission in 2023 (since July).

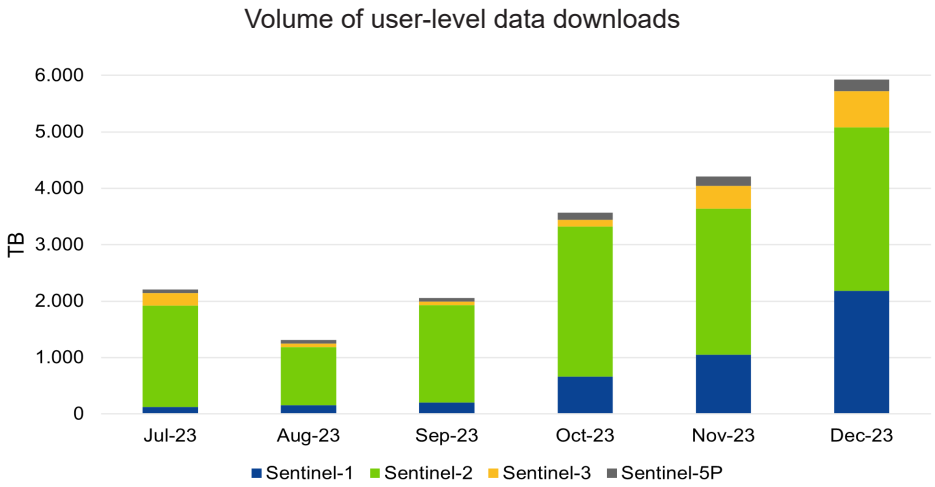


FIGURE 53: Dissemination volume trend using OData/Zipper interface, per month and mission in 2023 (since July).

Collection	Daily average volume [TB] downloaded in December 2023
Sentinel-1	70.20
Sentinel-2	94.15
Sentinel-3	20.58
Sentinel-5P	6.52
Total	**191.45**

TABLE 18: Average volume of data disseminated using OData/Zipper interface, during December 2023.

6.1.5. Data downloads per continent and per country

Another interesting view on download behaviour during 2023 is to examine the continents and individual countries that performed the most data downloads from the CDSE, and how this evolved since 2022. Table 19 and Figure 54 present the percentage of downloads (by volume) completed in each continent since July 2023.

In the second half of 2023, Europe remained the most active user of Copernicus Sentinel data, as in previous years, accounting for 74.6% of the total volume of user downloads from the CDSE.

When considering the number of downloaded products, the percentage distribution is very similar (Table 20).

Interestingly, the download activity varies significantly by continent for different Sentinel missions. Europe accounts for most downloads for all missions' data, except Sentinel-1, where over 50% of the downloads were made by North American users.

Table 21 provides further details on the spatial distribution of users and identifies for each Sentinel mission the top ten countries, in terms of users downloading data, among ESA member states.

Continent	Percentage of downloads
Europe	74.6%
North America	16.1%
Asia	6.1%
Africa	1.9%
South America	1.1%
Oceania	0.2%

TABLE 19: Percentage split of downloads using OData/Zipper interface, by volume per continent in 2023 (since July).

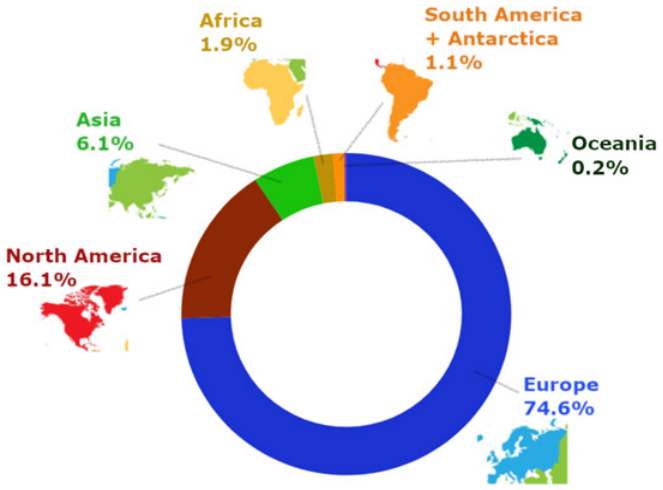


FIGURE 54: Percentage split of downloads using OData/Zipper interface, by volume per continent in 2023 (since July).

Continent	% of Sentinel-1 Downloads	% of Sentinel-2 Downloads	% of Sentinel-3 Downloads	% of Sentinel-5P Downloads	% of all missions Downloads
Europe	41.5%	86.0%	78.1%	71.9%	81.4%
North America	54.0%	8.8%	14.2%	15.8%	12.8%
Asia	3.6%	3.0%	7.6%	11.9%	3.9%
Africa	0.7%	1.5%	0.0%	0.0%	1.2%
South America	0.2%	0.7%	0.0%	0.3%	0.6%
Oceania	0.1%	0.1%	0.1%	0.1%	0.1%

TABLE 20: Percentage split of downloads using OData/Zipper interface, by number for each Sentinel mission and overall per continent in 2023 (since July).

#	Sentinel-1		Sentinel-2		Sentinel-3		Sentinel-5P	
	Country	Number of downloads	Country	Number of downloads	Country	Number of downloads	Country	Number of downloads
1	Italy	593,758	Austria	17,781,795	Italy	1,772,260	Ireland	807,722
2	France	188,321	Slovenia	6,889,974	France	1,708,217	Belgium	206,694
3	Spain	145,731	Italy	2,840,882	Germany	521,842	Germany	87,473
4	Luxembourg	145,642	Slovakia	2,178,781	Belgium	328,251	Italy	83,045
5	Denmark	83,850	Luxembourg	1525,804	United Kingdom	84,695	Romania	46,840
6	Austria	82,485	Belgium	540,331	Poland	66,381	France	45,317
7	Germany	43,097	France	379,478	Denmark	62,958	Netherlands	44,102
8	Sweden	37,982	Germany	284,743	Spain	48,118	Slovakia	31,096
9	Norway	19,244	Spain	268,568	Netherlands	34,492	Canada	28,894
10	Netherlands	18,403	United Kingdom	267,767	Canada	20,839	United Kingdom	17,080

TABLE 21: Top-10 ESA member states by number of Odata/Zipper downloads for each Sentinel mission in 2023 (since July).

6.2. Streamlined Data Access

One of the most significant changes introduced by CDSE compared to the previous Data Access Service is the ability to access and process data without the need for data download. The scalable processing applications are located in the cloud environment, allowing user to access pixels of data and apply both simple and complex processing tasks. CDSE takes away the technical complexity of accessing and processing data, enabling users to focus on their applications. Below we describe in detail the two main services for streamlined data access: Sentinel Hub and openEO.

6.2.1. Sentinel Hub

Sentinel Hub (SH) is a satellite imagery processing service capable of on-the-fly gridding, re-projection, re-scaling, mosaicking, compositing, orthorectification, and other actions required for streamlined data access for end-users. It can be integrated into web-applications, where images are mostly served, or into machine learning and similar data science processes, where pixel values and statistics are essential. Sentinel Hub works with original satellite data to preserve accuracy and uses cloud infrastructure and innovative methods to efficiently process and distribute data in a matter of seconds.

Application Programming Interface (API) is an intermediary that allows applications to access the features or data of another application or system. The Sentinel Hub API allows users to systematically process satellite data and integrate it into their own data analysis workflows and applications. Users can choose between an OGC (Open Geospatial Consortium) API, which enables integration of satellite data into desktop or online applications using the standard WMS, WCS, WMTS and WFS services, or the more powerful Sentinel Hub RESTful API.

For requesting large areas or longer time periods of data, Sentinel Hub includes a Batch Processing API, and for searching and viewing geospatial information, a STAC-compliant Catalog API is provided. Users interested in calculating statistical information from satellite imagery can use the Statistical API. Users can access all the data collections already integrated into Sentinel Hub or bring their own data.

Sentinel Hub APIs have been available for the CDSE users since July 2023, while the APIs powering the Copernicus Browser application have been operational since January 2023.

The most interesting highlights from the first period of operations (July - December 2023) are:

- Almost **150 million requests** were processed by Sentinel Hub services in this period.
- Over **450 million processing units** (PU) were consumed for streamlining Sentinel data. With one PU corresponding to approximately 26 km² of Sentinel-2 data processed at full resolution, the total represents almost 12 billion km² or **80 times the area of Earth landmass.** More than **100 trillion pixels** of data were processed along the way.
- More than 95% of all requests were made using **Copernicus Browser,** demonstrating strong community acceptance of the new application.
- Regarding the usage per data collection (Table 22 and Figure 55), **Sentinel-2 L2A** was the most requested (**66%** of all requests), followed by Sentinel-2 L1C (16%). The third most requested data collection were Sentinel-2 quarterly mosaics (9%) and Sentinel-1 GRD (5%). Sentinel-3 OLCI and SLSTR and Sentinel-5p, each contribute 2% or less.

Data collection offered in SH	% of all SH requests
Sentinel-1 GRD	5%
Sentinel-2 L1C	16%
Sentinel-2 L2A	66%
Sentinel-3 OLCI L1B	2%
Sentinel-3 SLSTR L1B	1%
Sentinel-5P L2	2%
Mosaics	9%

TABLE 22: Percentage of Sentinel Hub requests per data collection.

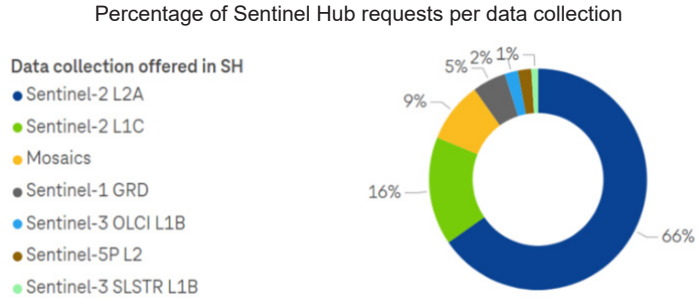


FIGURE 55: Percentage of Sentinel Hub requests per data collection.

In 2024, the data offer in Sentinel Hub will be expanded to include: Sentinel-3 L2, the newest version of Copernicus digital elevation model (DEM), quarterly Sentinel-2 and monthly Sentinel-1 mosaics covering the complete archive, Copernicus Contributing Missions, and other data.

Users will be further encouraged and supported to use the APIs directly, as this has a potential to significantly support, optimize and upscale processing in the Earth Observation community.

6.2.2. openEO

With the release of the openEO instance on the CDSE in June 2023, one of the most ambitious and novel services in the ecosystem became available. Via the openEO open standard, users can create end-to-end data access and processing workflows that produce maps at large scale, all the while avoiding the complexity of operating distributed processing clusters or parsing the various file formats in use by Copernicus user-level data.

The target audience of the openEO service ranges from data scientists who want to easily explore and analyse Copernicus data, to data engineers who aim to build production workflows. Thanks to this service, organizations and teams with limited IT resources can now build workflows that are automatically scaled across the cloud resources that are collocated with Copernicus data.

By directly supporting open science and FAIR principles, openEO tries to increase the quality of scientific output built on CDSE without adding extra burden on data scientists. Support for Python and the Pangeo ecosystem is included, as well as a client library for R and Javascript users (Figure 56).

Additionally, users have the option to use the web-based editor for openEO to carry out several EO data processing tasks, such as exploring the available datasets, defining processing steps, executing workflows, and visualizing the results. Thanks to its graphical user interface, users can build complex processing chains by connecting different processing steps as building blocks and define the specific parameters for each step.

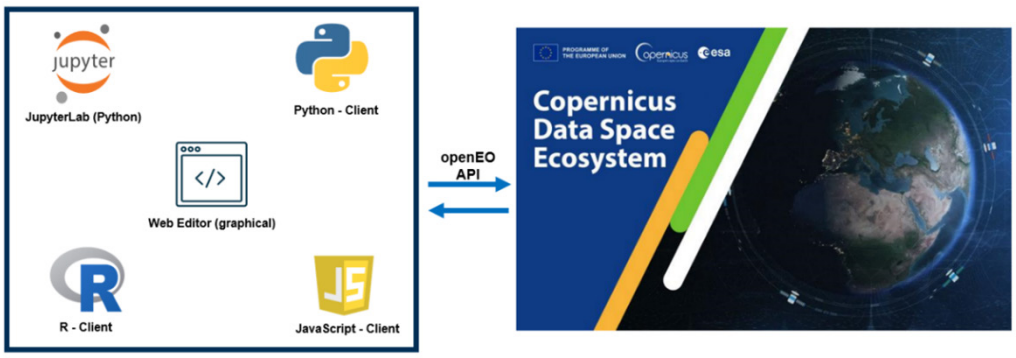


FIGURE 56: openEO API and its application in the Copernicus Data Space Ecosystem.

Figure 57 provides a glimpse of calculating NDVI, which is just a part of a more extensive workflow known as Parcel Delineation. In this broader workflow, parcel delineation is performed using Sentinel-2 data and a pre-trained deep learning model, showcasing the various algorithms that can be developed with openEO.

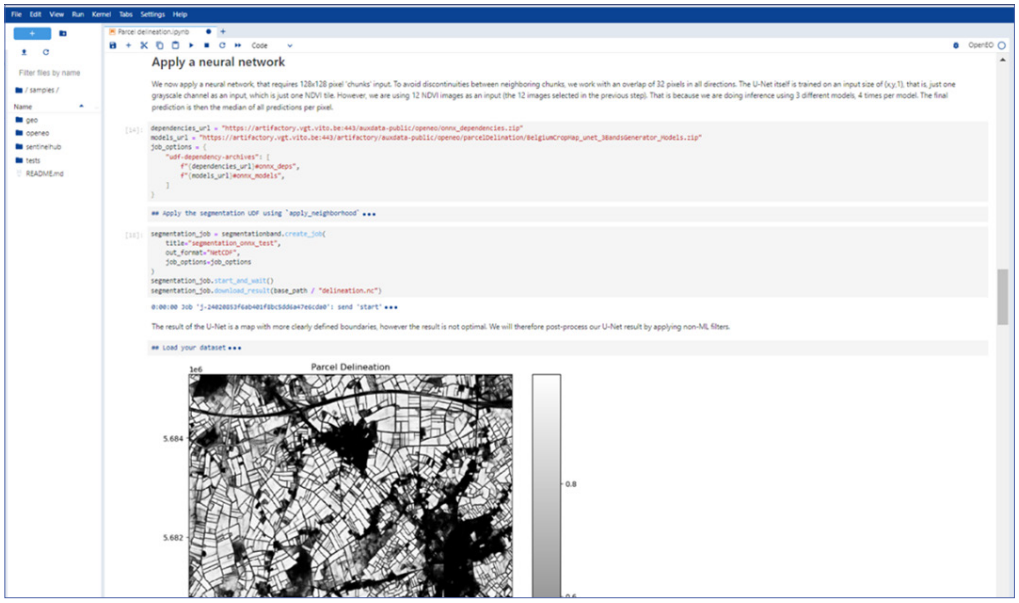


FIGURE 57: NDVI calculation making use of Parcel Delineation and deep learning in openEO.

Furthermore, the web editor, as mentioned earlier, is a user-friendly interface for creating block-style workflows. It provides an overview of available datasets and processes (Figure 58). Users can also easily monitor the status of their processing workflows using the web editor. It simplifies the workflow creation process by allowing users to drag and drop elements, making it accessible even to those who are not familiar with programming.

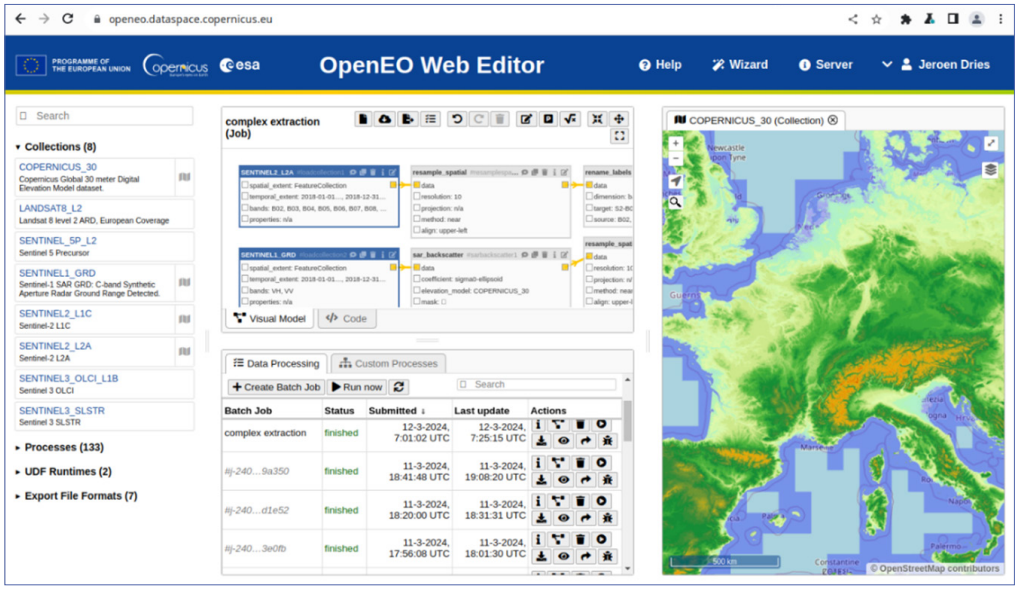


FIGURE 58: openEO web editor view.

Executing openEO processing workflows are linked to credits deduction, which is determined by factors like CPU usage, memory usage, and storage. Furthermore, if a workflow integrates services from the openEO Algorithm Plaza labelled as validated, verified, or operational, there may be additional costs.

In CDSE, each user is granted 4,000 free credits, which are replenished monthly. However, users can also request additional credits through ESA's Network of Resources, or purchase them through services like CREODIAS.

Marketplace

The openEO Algorithm Plaza is a marketplace within the CDSE that allows users to discover and share different EO algorithms expressed as openEO process graphs.

Each service, represented as a placard in Figure 59, has its dedicated page providing detailed information to briefly describe the methodology, expected results, and instructions for executing the service.

openEO Algorithm Plaza offers a wide range of services in Earth Observation. These services support algorithms ranging from simple computations like the Normalized Difference Vegetation Index (NDVI) to more complex algorithms that utilize machine learning and multiple parameters.

In addition to providing existing services, the marketplace also supports users in showcasing their algorithms as services in its catalogue. To advertise a service in the marketplace, the algorithm must be built using openEO.

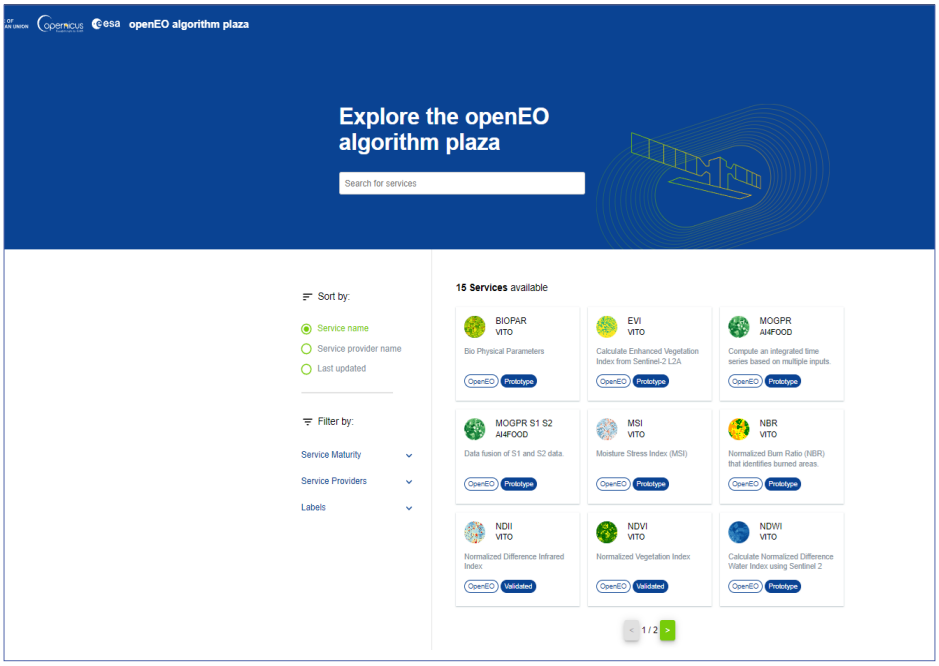


FIGURE 59: openEO Algorithm Plaza in the Copernicus Data Space Ecosystem.

Usage statistics

The target audience for openEO users encompasses individual data scientists and researchers to software developers and engineers, operating in a wide range of different thematic areas. The statistics shown here represent jobs that are submitted via the openEO API, but one job submitted can represent a single pixel, but also continental scale processing and everything in between. Within the range of the free-tier credits, a typical use case is the application of models and algorithms on a smaller local scale with batch jobs. Only after thorough finetuning and iterations to their models, scale up is typically done in larger scale projects.

Usage statistics for all request types in openEO show a steady increase from September 2023 onwards, following the June 2023 release. The increase seems to continue at a relatively constant rate in the first months of 2024, with expected seasonal variations for this type of service.

As the service is relatively new, there is not yet a large amount of repeated usage from operational processing workflows. Most organizations do need time to adopt these new technologies in their projects and usually start at smaller scale.

To provide a perspective on the level of use, it is worth looking at a project which produced crop type maps for the EU38 region over 5 years based on Sentinel-1 and Sentinel-2 data. Although this production filtered from the openEO statistics of CDSE, it is performed with the same software stack running in the same cloud environments. This processing volume is about 3 times larger than what CDSE openEO users generated in 2023, indicating significant growth potential as a large-scale map production is rolled out on the openEO CDSE service.

Figures 60 and 61 show the evolution over time of batch jobs and total requests. Batch jobs are used for heavier work, such as larger regions of interest, longer time series and more intensive processing. The total number of requests gives a general indication of usage but is not necessarily comparable across different types of services. In openEO, most of the work is performed via batch jobs, which require a limited number of requests to operate.

It was also observed that the number of unique users increased month after month, leading to a total of 642 unique users by the end of 2023. It is likely, therefore, that the higher number of batch jobs seen in the last two months of the year is mainly attributable to the higher number of users there were by the end of the year.

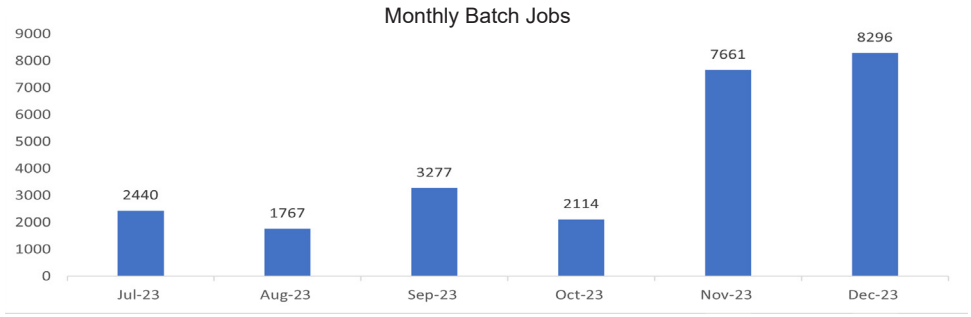


FIGURE 60: Trend of monthly openEO batch jobs in 2023.

FIGURE 61: Total openEO requests for June-December 2023.

openEO outlook for 2024

In 2024, the first global scale mapping projects are expected to perform their operational processing using the openEO service. In addition to that, several smaller scale projects will implement their workflows on top of openEO, increasing the variety of demonstrated use cases that are enabled by this platform. These projects will be driving the integration of new features and datasets, next to requests made by other users.

One usage pattern that influenced the CDSE roadmap is users generating datasets of multiple gigabytes in the netCDF format. While this was not entirely expected, we recognize that openEO offers a unique capability to generate such files, which are often more convenient to work with compared to the original data. Therefore, we have been making various improvements to stretch those size limits.

Another example is improved support for classification pipelines, using a variety of methods. These capabilities will be taken to a level where they are usable for operational global processing cases. Next to new features, ensuring the operational stability will remain a big focus of the openEO team.

In 2024, the openEO team also aims to start building an openEO based federation as part of the CDSE. The openEO standard has unique capabilities for federated processing, allowing the user to benefit from datasets and processing capacity that is available in multiple platforms.

To kick off this initiative, the team will start with the integration of the TerraScope platform. This integration will enable CDSE openEO users to effortlessly access TerraScope datasets, including but not limited to PROBA-V.

The team also dedicated efforts to support the user onboarding. These efforts have resulted in user-friendly videos and guides to help individuals in getting started with openEO. These resources walk users through basic aspects, such as using the openEO Python library, creating and executing algorithms using a web editor, and exploring the openEO Algorithm Plaza. Furthermore, the online documentation portal has been extended with examples illustrating how openEO can be used for various Earth Observation applications, ranging from basic (indices computation) to advanced (machine learning). As we continue to enhance our offerings, we anticipate more videos and examples to be added over time.

The openEO tutorials can be accessed on YouTube here:

Authenticate your account using openEO API (Python)

Introduction to openEO Algorithm Plaza

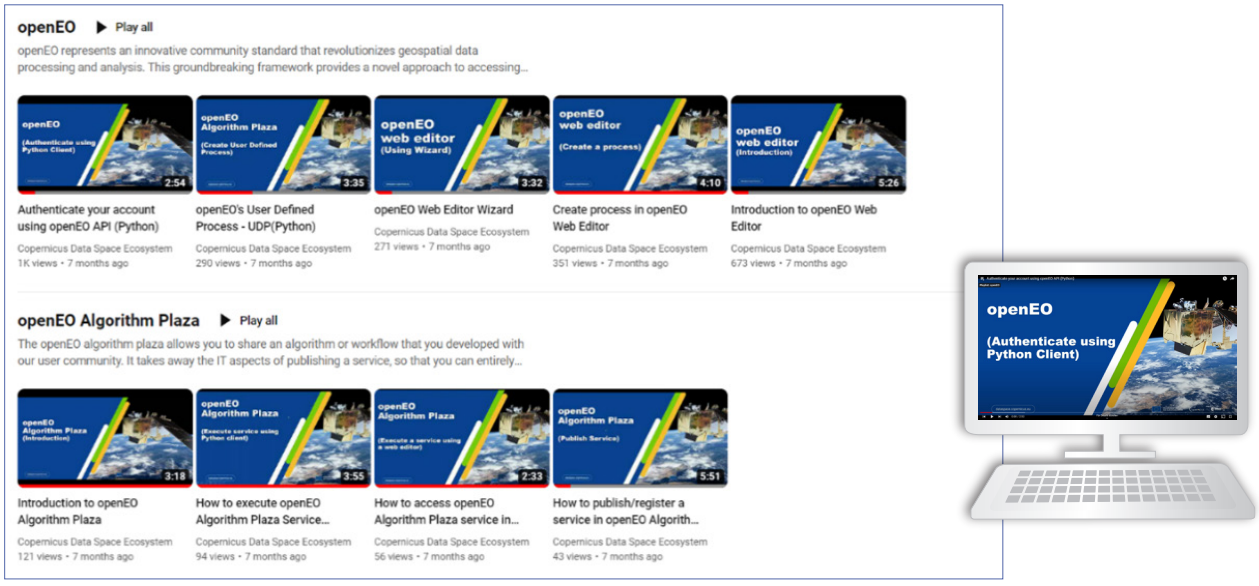


FIGURE 62: Overview of openEO tutorials on YouTube.

7 USER ACTIVITY

In the previous sections we presented the number of registered users, related data download and service usage. In this section, we present a more detailed analysis of user activities and trends in service usage.

7.1. Visitor trends

The Copernicus Browser experienced 601,500 visitors throughout 2023, and this culminated in 1.1 million views. Figure 63 clearly shows the rapid increase in activity following the go-live in the second half of the year and the closure of the former Sentinel Data Access Service at the end of October.

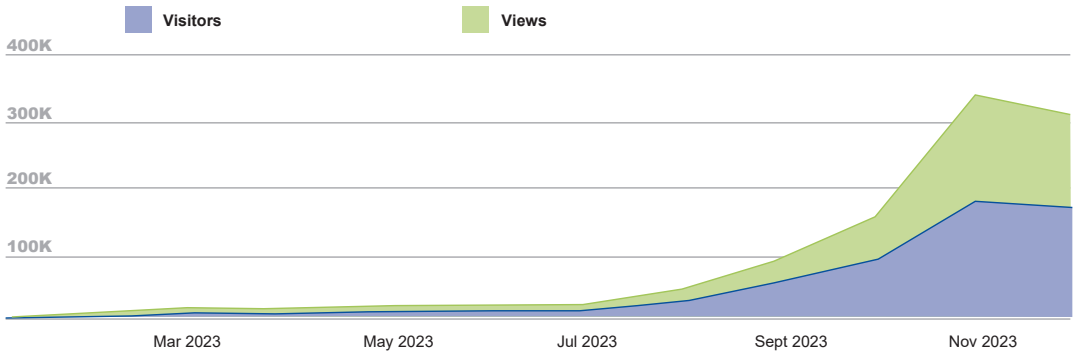


FIGURE 63: Growth of Copernicus Browser visitors and views in 2023

Figure 64 breaks this activity on the Copernicus Browser down by continent. It can be seen that the mass take-up of the Copernicus Browser service started first in Europe and Asia, whereas users in the other continents began rapidly multiplying in December. After a slow start, there were actually more users in North America in the last week of December than there were in Europe, and although the total number of users from Europe overall remained higher (see Figure 65 below), the number of users from Asia was twice that of Europe in the last week of December.

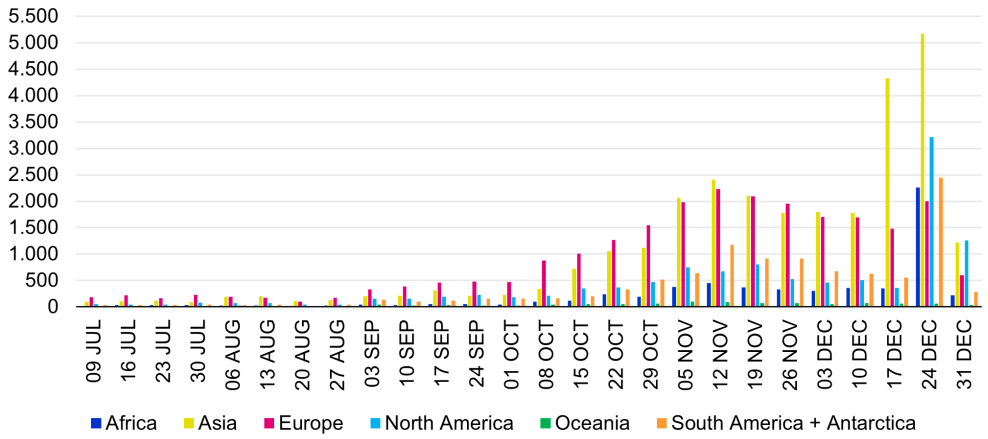


FIGURE 64: Trend of visitors per continent and per calendar week in 2023 (since July).

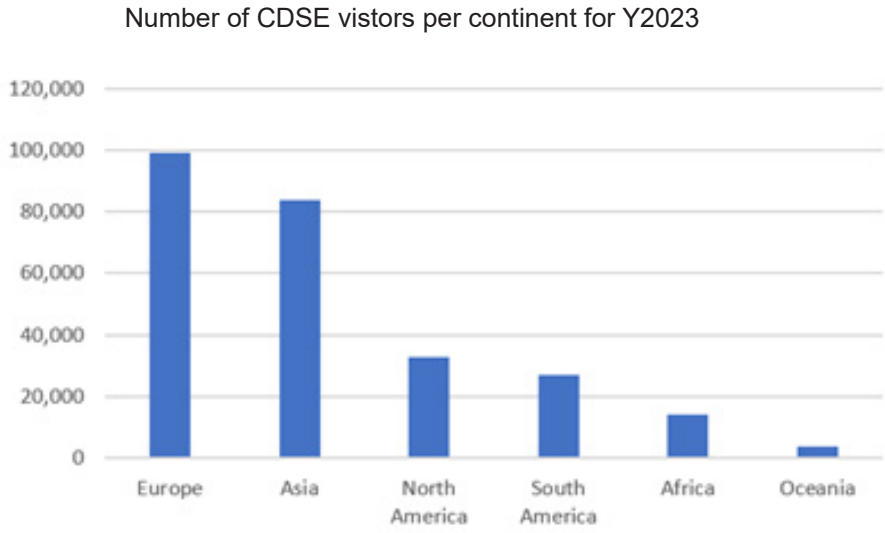


FIGURE 65: Total visitors per continent in 2023 (since July).

Date	Africa	Asia	Europe	North America	Oceania	South America + Antarctica
09 JUL	18	100	185	53	8	33
16 JUL	35	112	219	47	8	38
23 JUL	33	123	166	48	12	34
30 JUL	34	88	226	77	18	47
06 AUG	28	194	190	75	24	37
13 AUG	30	206	174	75	19	48
20 AUG	18	106	96	43	6	21
27 AUG	25	130	176	48	14	45
03 SEP	47	199	333	160	42	134
10 SEP	39	214	389	160	28	101
17 SEP	50	313	462	190	32	119
24 SEP	55	207	480	233	24	152
01 OCT	48	227	472	186	22	154
08 OCT	100	339	879	212	41	164
15 OCT	119	719	1,011	353	56	202
22 OCT	238	1,054	1,272	370	56	335
29 OCT	192	1,115	1,549	472	60	518
05 NOV	375	2,066	1,979	753	103	634
12 NOV	448	2,407	2,229	676	92	1,179
19 NOV	373	2,100	2,095	801	69	913
26 NOV	332	1,780	1,953	526	74	915
03 DEC	302	1,794	1,705	463	56	677
10 DEC	360	1,779	1,697	509	73	628
17 DEC	354	4,325	1,484	356	59	554
24 DEC	2,263	5,173	1,997	3,213	59	2,442
31 DEC	220	1,226	598	1,260	38	281

TABLE 23: Trend of visitors per continent and per calendar week in 2023 (since July).

7.2. User download profiles

In this section, users are categorised according to the number of downloads they performed throughout the period July to December 2023. All Sentinels are considered.

Table 24 presents the ranges of downloads performed by users split by mission. The "Range" column indicates the number of user-level data downloads made by a user during the period.

The general trend indicates that the vast majority of active users for each mission downloaded between 1 to 9 data packages. The number of users decreases as the download range gets higher, for all missions other than Sentinel-5P, for which more users downloaded in the 100-1,000 range than in the 10-100 range. These statistics are also illustrated in Figure 66.

The most popular mission was Sentinel-2, with 21,048 users downloading between 1 to 9 data packages, 5,858 users downloading between 10 to 100, 1,343 users downloading between 100 to 1,000, and 741 users downloading more than 1,000 data packages.

Range	Collection			
	Sentinel-1	Sentinel-2	Sentinel-3	Sentinel-5P
1-9	5,271	21,048	1,632	754
10-100	1,566	5,858	374	177
100-1,000	690	1,343	337	352
1,000+	124	741	185	106

TABLE 24: User download profile July-December 2023.

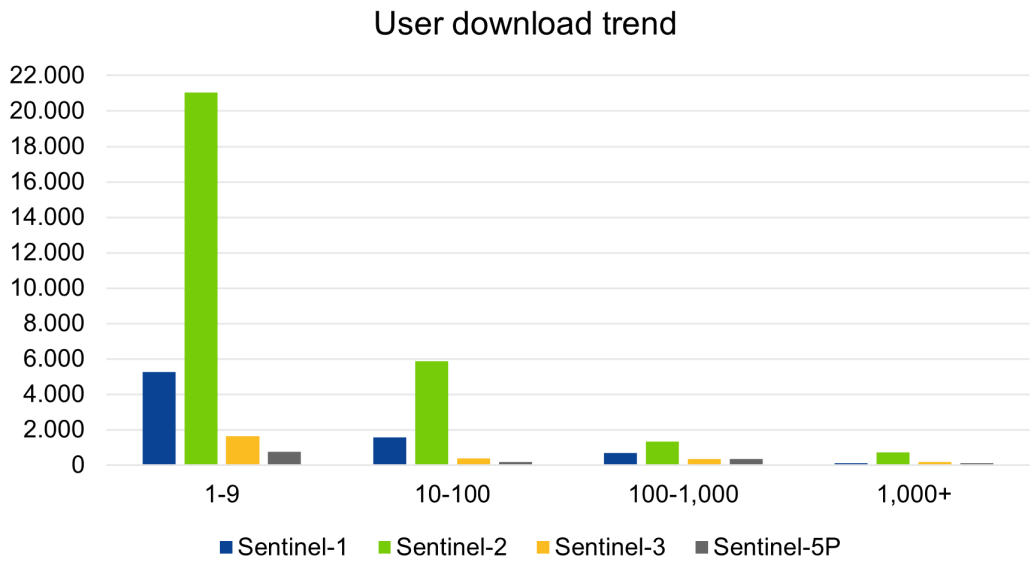


FIGURE 66: User download trend July-December 2023.

7.3. Monthly active users

Figure 67 shows the number of active users per month from July to December 2023. October was the month when a lot of users registered for the new service and started downloading data. The highest peak in active users occurred in November, primarily driven by Sentinel-2 data. In November, 15,063 active users downloaded Sentinel-2 data, which is more than double the amount of Sentinel-2 active users recorded for the previous month.

The activity of the users shows a clear correlation with the upsurge in the number of registered users and visitors in the last months of 2023.

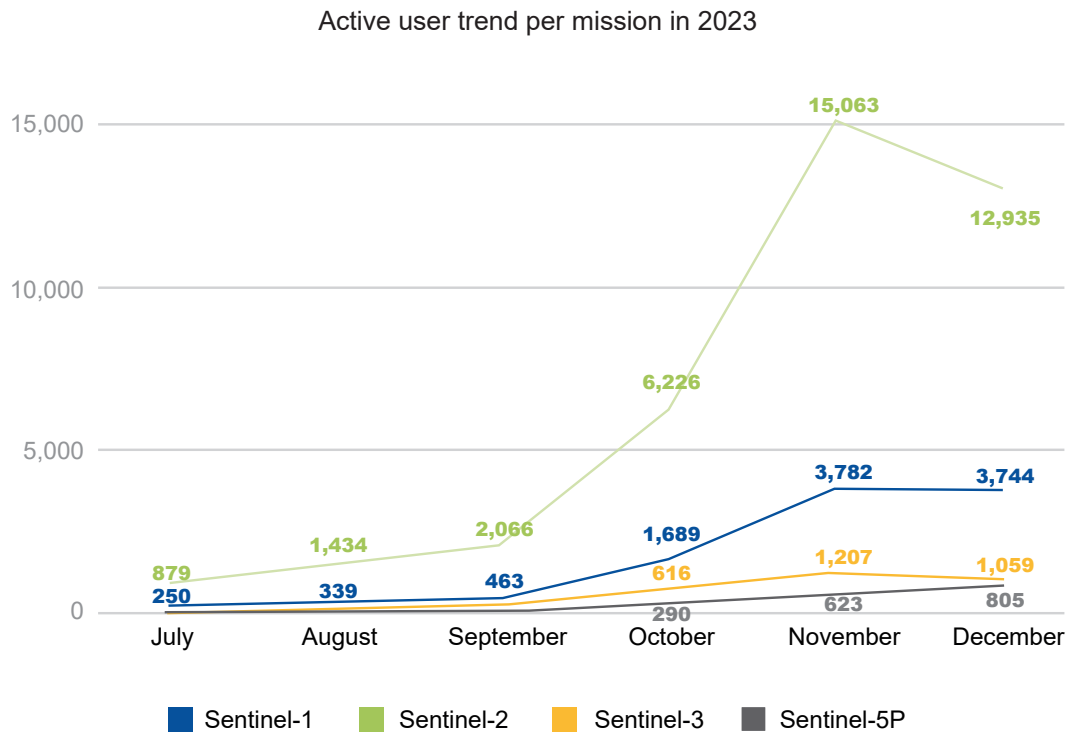


FIGURE 67: Active users' trend per mission in 2023 (July-December).

7.4. Monthly users per continent and country

The registration phase includes the collection of user information (e.g., user country, thematic domain, and usage type) selected by the user from a set of predefined lists. There is no active verification of the information entered, so the statistics presented here rely on the self- registered data being accurate.

Figure 68 shows the number of active users broken down by continent for 2023 (July – December).

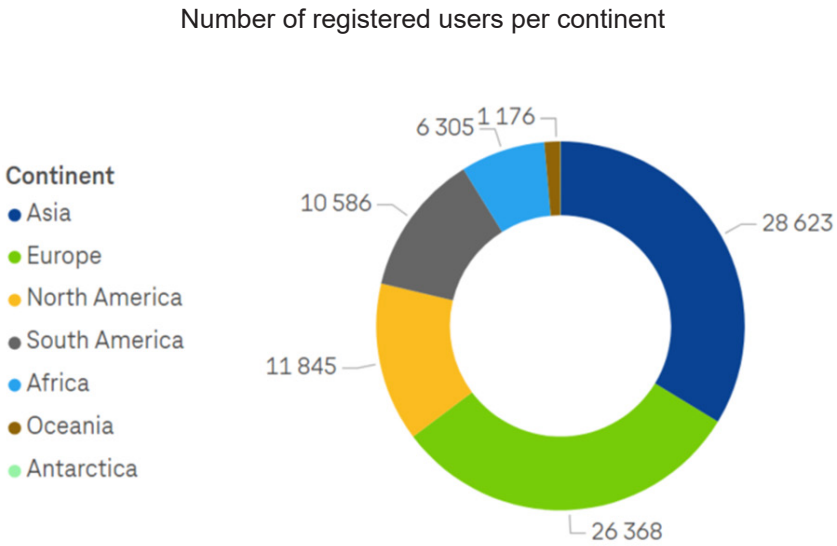


FIGURE 68: CDSE active users per continent for 2023.

It is worth mentioning that the number of active users does not give any information about the volume of data downloaded by those users. To count as an active user, it does not matter whether the user downloaded only one or a thousand user-level data packages; the user is still counted as one active user.

The following eight Tables (25-32) present the Top-10 active users by country for all Sentinels, both globally and at the EU/ESA member state level (countries that are a member of either EU or ESA).

As active users were only counted for the second half of 2023, the change in ranking compared to 2022 is simply provided as an approximate indication.

N/A indicates that the number of users for a country was not among the Top 10 in 2022 and was therefore not included in the report. For Sentinel-5P, the number of active users in 2022 was not reported.

Sentinel-1 Global			
Country	**Active Users 2023 (from July)**	**Ranking 2022**	**Change**
China	1,303	1	0
United States	603	3	+1
India	424	2	-1
Italy	383	5	+1
Germany	347	4	-1
France	287	9	+3
Indonesia	255	6	-1
Spain	239	8	0
Brazil	196	N/A	N/A
United Kingdom	189	7	-3

TABLE 25: Top 10 countries in the world by number of active Sentinel-1 users, and comparison of rankings in 2023 versus 2022.

Sentinel-2 Global			
Country	**Active Users 2023 (from July)**	**Ranking 2022**	**Change**
China	3,839	1	0
India	1,662	6	+4
United States	1,597	5	+2
Indonesia	1,590	N/A	N/A
Brazil	1,572	3	-2
Spain	1,297	2	-4
Germany	1,260	4	-3
Italy	1,021	7	-1
France	727	10	+1
Colombia	614	9	-1

TABLE 26: Top 10 countries in the world by number of active Sentinel-2 users, and comparison of rankings in 2023 versus 2022.

Sentinel-3 Global			
Country	**Active Users 2023 (from July)**	**Ranking 2022**	**Change**
United States	366	1	0
China	349	2	0
Italy	161	4	+1
France	147	7	+3
Germany	136	3	-2
Spain	111	6	0
India	102	5	-2
Poland	67	10	+2
United Kingdom	56	8	--1
Brazil	53	9	-1

TABLE 27: Top 10 countries in the world by number of active Sentinel-3 users, and comparison of rankings in 2023 versus 2022.

Sentinel-5P Global			
Country	**Active Users 2023 (from July)**	**Ranking 2022**	**Change**
China	277	N/A	N/A
United States	272	N/A	N/A
Italy	72	N/A	N/A
India	70	N/A	N/A
France	53	N/A	N/A
Poland	53	N/A	N/A
Germany	50	N/A	N/A
Spain	36	N/A	N/A
Great Britain	35	N/A	N/A
Brazil	26	N/A	N/A

TABLE 28: Top 10 countries in the world by number of active Sentinel-5P users, and comparison of rankings in 2023 versus 2022.

Sentinel-1 EU/ESA			
Country	**Active Users 2023 (from July)**	**Ranking 2022**	**Change**
Italy	383	2	+1
Germany	347	1	-1
France	287	5	+2
Spain	239	4	0
United Kingdom	189	3	-2
Poland	169	6	0
Canada	127	N/A	N/A
Netherlands	97	7	-1
Greece	70	8	-1
Portugal	62	10	0

TABLE 29: Top 10 ESA/EU countries by number of active Sentinel-1 users, comparing rankings in 2023 versus 2022.

Sentinel-2 EU/ESA			
Country	**Active Users 2023 (from July)**	**Ranking 2022**	**Change**
Spain	1,297	1	0
Germany	1,260	2	0
Italy	1,021	3	0
France	727	4	0
United Kingdom	596	5	0
Poland	589	6	0
Greece	550	7	0
Canada	446	N/A	N/A
Netherlands	323	8	-1
Portugal	256	9	-1

TABLE 30: Top 10 ESA/EU countries by number of active Sentinel-2 users, comparing rankings in 2023 versus 2022.

Sentinel-3 EU/ESA			
Country	**Active Users 2023 (from July)**	**Ranking 2022**	**Change**
Italy	161	2	+1
France	147	4	+2
Germany	136	1	-2
Spain	111	3	-1
Poland	67	6	-1
United Kingdom	56	5	-1
Greece	37	8	+1
Canada	31	N/A	N/A
Netherlands	29	7	-2
Switzerland	26	N/A	N/A

TABLE 31: Top 10 ESA/EU countries by number of active Sentinel-3 users, comparing rankings in 2023 versus 2022.

Sentinel-5P EU/ESA			
Country	**Active Users 2023 (from July)**	**Ranking 2022**	**Change**
Italy	72	N/A	N/A
France	53	N/A	N/A
Poland	53	N/A	N/A
Germany	50	N/A	N/A
Spain	36	N/A	N/A
United Kingdom	35	N/A	N/A
Netherlands	24	N/A	N/A
Canada	14	N/A	N/A
Greece	11	N/A	N/A
Czech	10	N/A	N/A

TABLE 32: Top 10 ESA/EU countries by number of active Sentinel-5P users, comparing rankings in 2023 versus 2022.

7.5. Users per declared uses and thematic domains

Table 33 sets out the thematic domains selected by the 2023 active users when they registered for access to the CDSE. It can be seen that the domains with the highest numbers of active users are: land, 'other', research and development, climate change, and environmental compliance, which together account for 92% of all active users (Table 33 and Figure 69).

Table 34 groups the number of downloads per Sentinel according to user-declared thematic domain. It shows that the majority of Sentinel-1 downloads were made by users whose activities are grouped under the bracket 'other'.

Most of the Sentinel-2 downloads were made by users who selected 'Land' as their thematic domain when they registered, although almost 7,000 downloads were made by users who selected 'other'. Sentinel-3 data was also primarily used for land analysis, with a similar number of downloads made by users who indicated 'other' domains. By far the majority of Sentinel-5P downloads was made by active users who selected 'climate change' as their thematic domain.

Thematic domain	# of active users	% of active users
Air quality and atmospheric composition	550	2%
Arctic policy and polar areas	145	1%
Civil protection and humanitarian aid operations	312	1%
Climate Change	2,771	10%
Energy	314	1%
Environmental compliance	2,369	9%
Land	9,836	36%
Raw materials	208	1%
Research and innovation	5,451	20%
Security	179	1%
Tourism	146	1%
Transport & Health & International development and cooperation & Migration and home affairs	355	1%
Other	4,800	17%

TABLE 33: Number and percentage of CDSE active users per thematic domain in 2023 (since July).

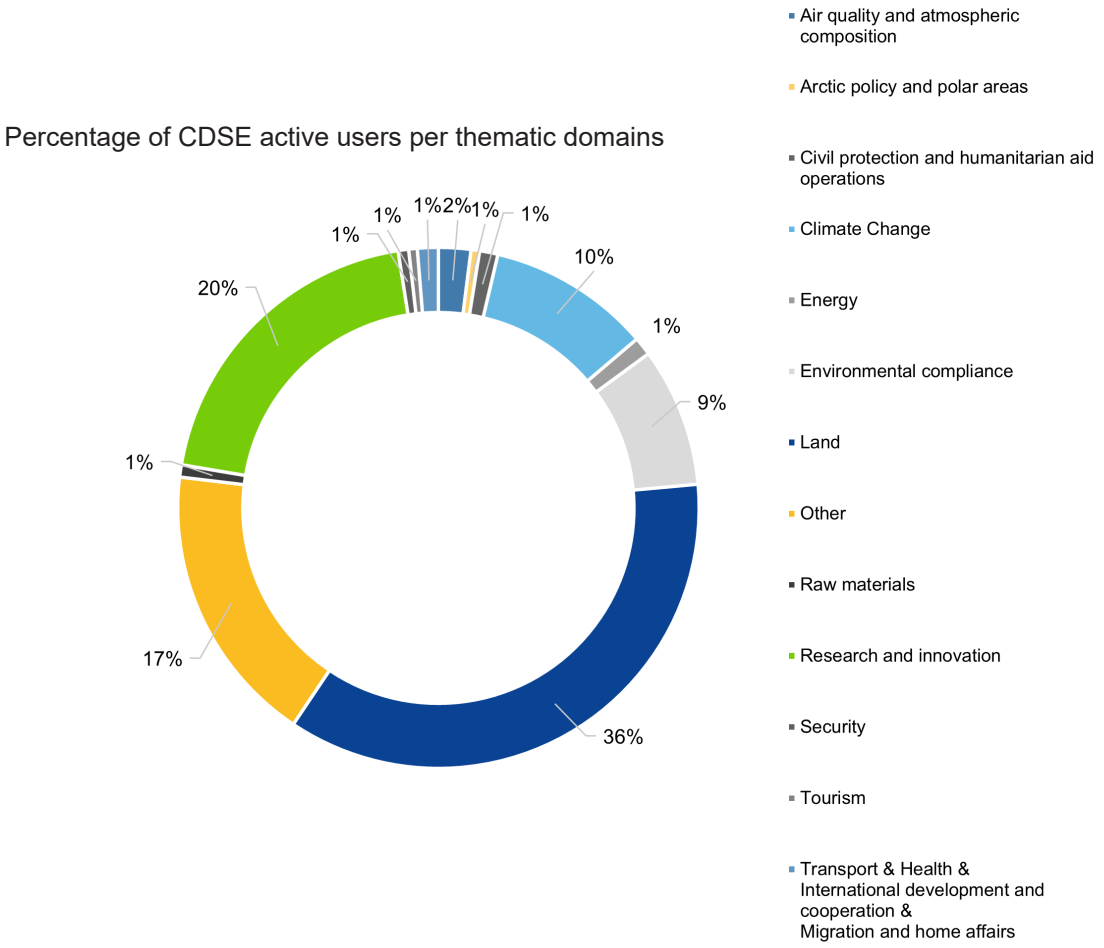


FIGURE 69: Percentage of CDSE active users per thematic domains.

Thematic activity	Sentinel-1	Sentinel-2	Sentinel-3	Sentinel-5P
Air quality and atmospheric composition	575	14,982	23,223	279,028
Arctic policy and polar areas	6,125	8,559	103,853	6
Civil protection and humanitarian aid operations	49,803	9,887	11,481	8
Climate Change	84,122	98,926	406,599	1,046,759
Energy	22,420	6,853	6,490	2,296
Environmental compliance	22,732	66,166	41,652	29,332
Health	96	2,093	539	121
International development and cooperation	5,220	4,664	151,495	247
Land	122,574	18,927,599	1,644,835	87,385
Migration and home affairs	218	240	3	0
Raw materials	1325	13,938	49,961	5
Research and innovation	294,926	1,025,214	883,085	159,297
Security	6,145	5,131	110	3,714
Tourism	1,059	3,543	959	5
Transport	2,053	4,204	44	61
Other	1,655,457	6,768,865	1,789,500	12,760

TABLE 34: Number of downloads performed for Sentinel-1, -2, -3 and -5P for each thematic domain during 2023 (since July).

Figure 70 shows the number and percentage of active users per user-declared organization type. Users are presented with a list of seven organization types from which they can choose on registration. More than half (55%) of the active users come from research and education organisations, with personal interest coming in second. However, users in the 'research and education' category only accounted for just over 10% of the total number of downloads (Table 35 and Figure 71). The most downloads were made by users from

international public organizations, who made almost 45% of the total number of downloads, despite representing only 3% of active CDSE users.
Nearly 30% of data downloads were made by users of from the 'other' category.

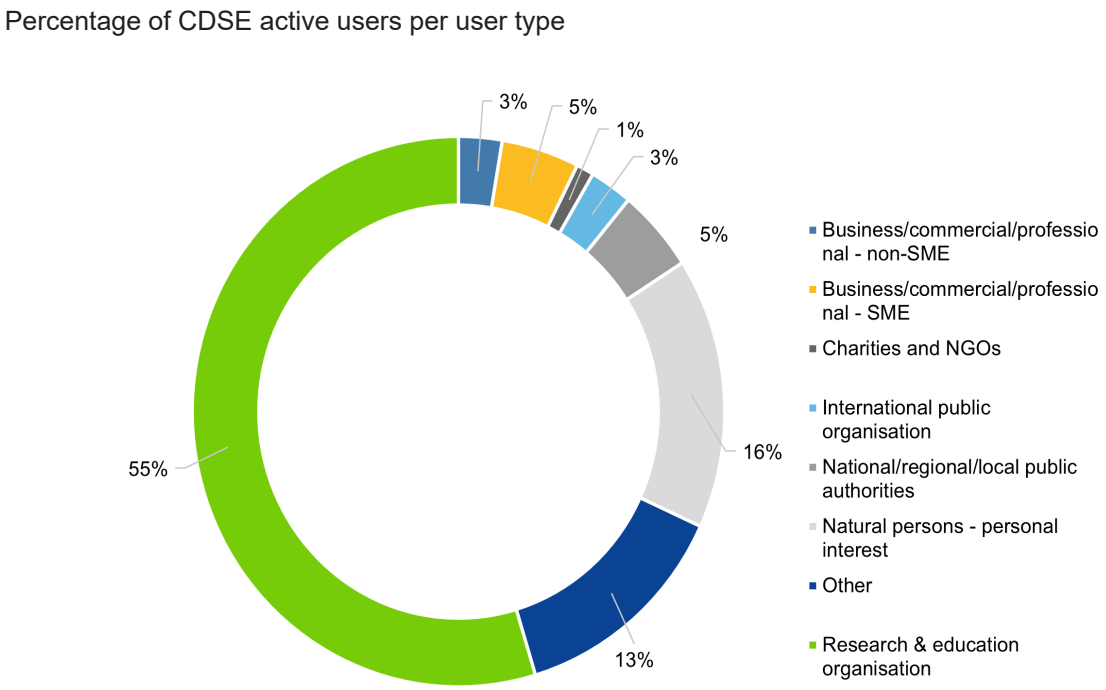


FIGURE 70: Percentage of CDSE active users per user type in 2023 (since July).

Type of user	Sentinel-1	Sentinel-2	Sentinel-3	Sentinel-5P
Business/commercial/professional – non-SME	103,618	3,575,865	139,763	112,894
Business/commercial/professional – SME	270,858	890,367	2,202,918	104,852
Charities and NGOs	33,885	115,634	6,424	26,515
International public organization	443,573	21,877,913	202,086	21,843
National/regional/local public authorities	341,918	372,775	58,458	214,094
Natural persons – personal interest	27,717	345,435	60,610	37,908
Research & education organization	1,473,805	1,210,976	1,214,153	1,362,091
Other	845,454	10,834,053	2,172,348	80,618

TABLE 35: Number of downloads performed for Sentinel-1, -2, -3, and -5P for each type of user during 2023 (since July).

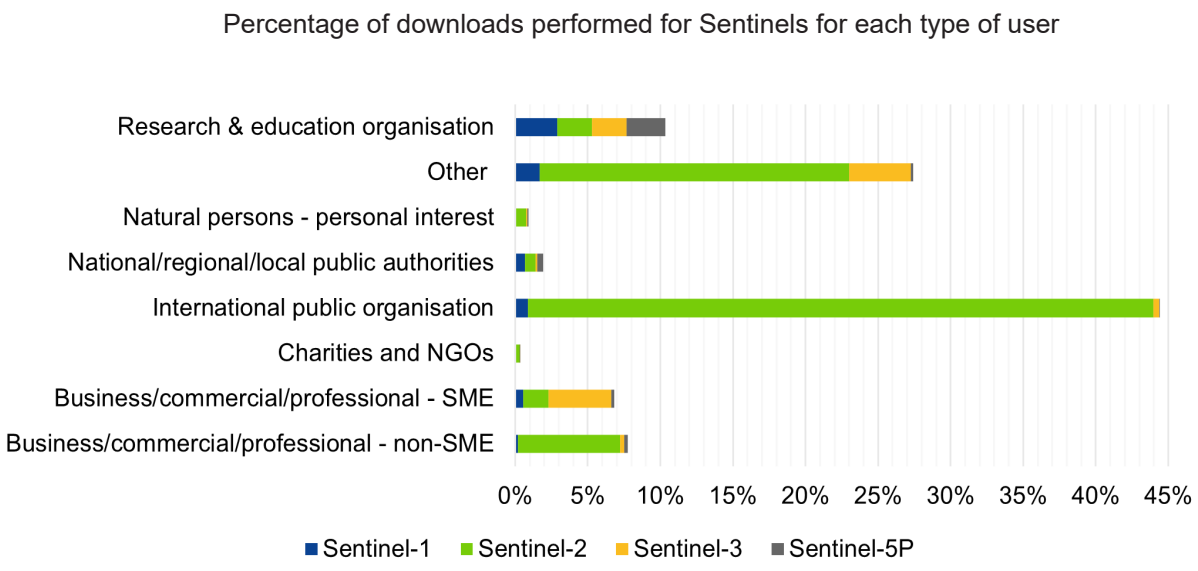


FIGURE 71: Percentage of downloads performed for Sentinel-1, -2, -3, and -5P for each type of user during 2023 (since July).

Table 36 shows that more than 75% of active users had selected 'research' or 'education' as their intended data use when they registered for the CDSE. Yet, these purposes do not account for most of the downloads, as 65% of downloads (notably almost all of the Sentinel-2 data) were made by active users who had selected 'other' as their intended purpose (Table 37).

Domain	# of active users	% of active users
Businesses sector	1,246	4%
Charities and NGOs	264	1%
Education	12,130	41%
Media and public relations purposes	80	0.3%
Natural persons for non-commercial purposes	1,619	5%
Public sector	1,661	6%
Research	10,683	36%
Other	1,963	7%

TABLE 36: Number and percentage of CDSE active users per purpose of use in 2023 (since July).

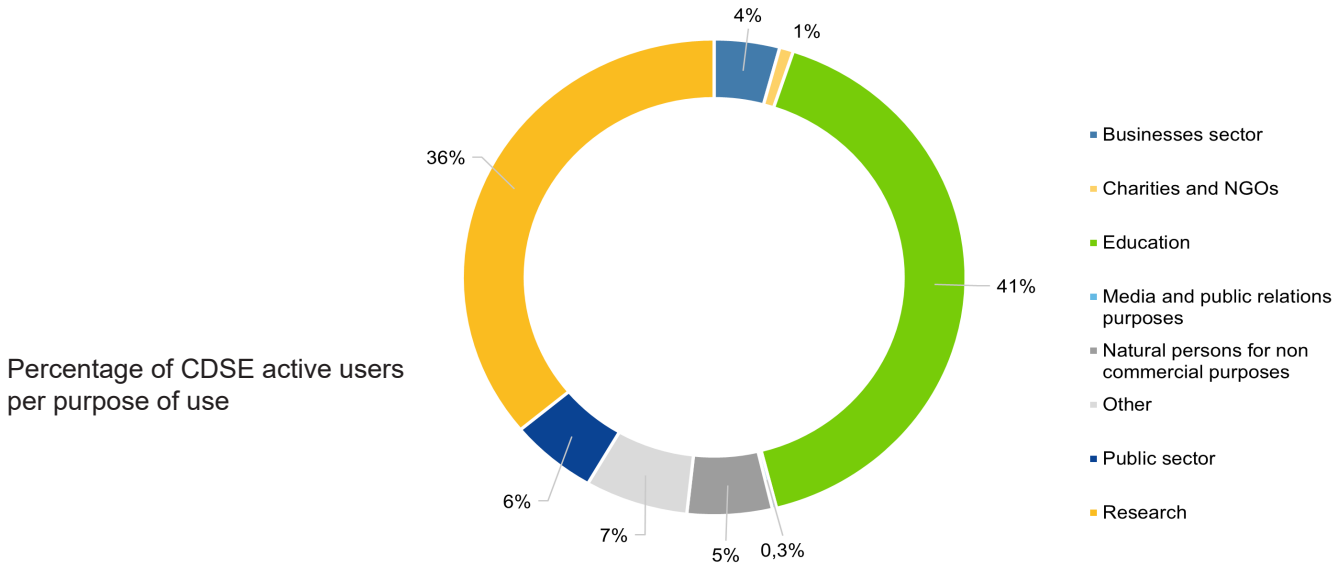


FIGURE 72: Percentage of CDSE active users per purpose of use in 2023 (since July).

Purpose of use	Sentinel-1	Sentinel-2	Sentinel-3	Sentinel-5P
Businesses sector	80,206	765,604	1,543,759	61,890
Charities and NGOs	35,264	119,650	10,074	26,689
Education	40,268	185,837	24,517	42,461
Media and public relations purposes	188	4,773	42	15
Natural persons for non-commercial purposes	7,069	68,370	6,808	18,993
Public sector	717,487	372,041	380,349	1,033,739
Research	545,789	1,512,092	1,008,505	446,794
Other	1,727,181	24,470,218	2,146,071	15,356

TABLE 37:
Number of downloads performed for Sentinel-1, -2, -3, and -5P for each purpose of use during 2023 (since July).

8 OUTREACH AND ENGAGEMENT

The Copernicus Data Space Ecosystem consortium is highly active in its outreach and engagement activities, ensuring that all upcoming events are announced in the EVENT section on the CDSE website: https://dataspace.copernicus.eu/events. Peaks in the number of registered users often coincide with international conferences where CDSE is represented or where there is significant presence of Earth Observation (EO) and Copernicus initiatives. In addition to conferences, CDSE leverages various channels to reach different target audiences. These include social media platforms such as LinkedIn, Facebook, and YouTube, where news, technical documentation, and tutorial videos are regularly shared. Workshops, webinars, and outreach events hosted by consortium partners throughout the year also play a crucial role in spreading awareness and generating interest.

The communication campaigns of the CDSE consortium target a diverse range of audiences, including application developers, data scientists, journalists, the general public, policymakers, educators, agricultural stakeholders, and startups. Each group is engaged through tailored channels and content, ensuring that the platform's capabilities and benefits are effectively communicated to maximize user registration and participation. This comprehensive approach helps in spreading awareness and fostering a broader user base, making the Copernicus data more accessible and useful to various communities.

8.1. Communication objectives in 2023

Phase-in period

- provide information to current users of the Hubs to support their migration
- raise awareness of upcoming capabilities until July 2023

Overall objectives

- traise awareness of the Copernicus data among general population and policy makers
- build trust in the services and the data among researchers and service providers
- communicate service capabilities
- communicate service evolution plans (roadmap, maintenance works) showcase the use of services and data in specific domains to broaden its application gather feedback from various user communities on relevant existing and future functionalities.

8.2. Communication channels

The structure of the CDSE communication channels is as follows:

- Web portal: regular news updates are released for additional features or datasets, and the image gallery provides attractive content for newcomers to earth observation. Users can also subscribe to the CDSE RSS feed at: https://dataspace.copernicus.eu/rss.xml.
- Social media: news features, videos and blog posts are also communicated through the social media channels (Twitter, LinkedIn, Facebook) of the consortium partners, who together have a following of about 50,000. CDSE-related content is also shared on the Copernicus and EU Space Office channels, which have about 100 000 followers. Social media posts that directly reach specific user community (such as QGIS) have been especially popular.
- CDSE Youtube: this channel collects all technical video tutorials and manuals for CDSE, with videos currently having several hundred to several thousand views. You can find it on: https://www.youtube.com/@copernicusdataspaceecosystem

8.3. Onsite events

In 2023, there were numerous community events, at which CDSE was promoted within the scientific community and among related stakeholders. The presentations at these conferences provided rich educational and onboarding materials for prospective user communities. Additionally, the feedback received during these events helped assess priorities and shape the future development of CDSE. Among the events the following are especially worth mentioning:

- **EGU General Assembly** Vienna, Austria, Conference 2023-04-24 – this conference was an opportunity to address a very wide and diverse audience in science and industry. The main communication channels were a system of demonstrations at the ESA booth and a townhall meeting. Most participants were not familiar with CDSE before.
- **25th anniversary of Copernicus**, Stockholm, Sweden, Conference, 2023-06-08 – this conference was an opportunity to showcase CDSE to many users who are already actively engaged in EO. CDSE has been presented as a key component of the Copernicus program.
- **EXPANDEO 2023**, Brussels, Belgium, Conference, 2023-06-13/14 – this conference is one of the main forums of the Earth Observation industry. CDSE was featured in a dedicated session including both an overview and technical demonstrations, in addition to a booth where participants could ask questions. The presentation was particularly well received and generated substantial interest in follow-up, especially in the fields of CAP monitoring and, environmental law and EO education. A video of the demonstration has been available: https://www.youtube.com/watch?v=A4I_7CvHFUY
- **Ministerial Congress Germany,** Berlin, Germany, Conference 2023-09-13/14 – CDSE solutions were presented to policy stakeholders, demonstrating the operational use of the platform for monitoring and disaster response.
- **INTERGEO 2023**, Berlin, Germany, Conference 2023-10-10/12 - this is one of the largest conferences of the EO industry. CDSE was represented at a sponsor booth, providing an opportunity to interact with users from a wide range of backgrounds.
- **Webinar: Introduction to CREODIAS 2.0 Webinar** 2023-10-19 – this webinar, staffed by all consortium partners, provided a walkthrough of commercial opportunities in CREODIAS and showcased case studies. In addition to the 180 live participants, the recording of the webinar continues to be viewed online.
- **Big Data from Space 2023**, Vienna, Austria, Conference and Exhibition, 2023-11-06/09 – CDSE was prominently featured at this conference, with a booth, a side event (see below) and additional live demonstrations, posters, and presentations. Especially the live demos highlighted how CDSE breaks the boundaries of the classical approach to remote sensing (data download and local processing). One-on-one consultations were provided to current and prospective users at the booth and feedback was collected and discussed at the consortium level.
- **Jupyter Notebook tutorial at BiDS 2023**, online Workshop, 2023-11-06 – this side event provided a full-scale hands-on tutorial to 40 participants, showing how they can carry out end-to end processing at continental scale without setting up any local processing environment. The participants were from a wide range of backgrounds (startups, government agencies, EO companies, research).
- **EU Space week**, Sevilla, Spain, Conference and Exhibition, 2023-11-07/09 – CDSE was presented at a conference booth.
- **Smart Country Convention**, Berlin, Germany, Conference, 2023-11-07/09 – CDSE was showcased in an oral presentation and a panel discussion. This event focused on policymakers and government agencies.
- **Websummit 2023**, Lisbon, Portugal, Conference and Exhibition, 2023-11-13/16 – CDSE was presented at the booth of DG DEFIS.
- **New Space Economy Forum**, Rome, Italy, Conference, 2023-12-05/07 – CDSE was presented at a conference booth.

8.4. Image gallery

The CDSE provides a wealth of satellite data for several use cases. Through the online CDSE image gallery, users can easily search, access, and download satellite images from the Copernicus Sentinel satellites and contributing missions.

CDSE engages actively with its users by sharing at least four captivating satellite images every month. These images showcase the global reach of satellite data, the diversity of our global landscape, and the ever-increasing need to constantly monitor our Earth. This monitoring is essential to measure the effects of, among other things, climate change and population increase. By providing these accessible and appealing images, we highlight the indispensable role of satellite technology in understanding and enhancing our planet.

The image gallery is updated on a regular basis to highlight use cases, global events and CDSE-related news activities. Each gallery item may contain one or more satellite images, depending on the topic we aim to emphasize, such as a specific location or date, timelapse, or images with zooms. For each image gallery topic, CDSE provides:

- Clean satellite image(s)
- Edited satellite image(s) with annotations to highlight important elements in the landscape
- High-resolution images(s) for download & external use
- Content to inform people about the satellite data, event and location (landscape)
- Animated GIF or video (sporadic).

8.5. Follow-up and lessons learned in 2023

The main task in 2023 was to make users aware of the opportunities CDSE provides and to introduce it as the default access point to Sentinel data. Both the EO community and government agencies have shown high interest in the new tools and services. The general public also has new opportunities for data access such as for the open-source intelligence community or NGOs. Interest is especially high in the open-source GIS and university education communities. Still, many user groups are not sufficiently aware of the existence of CDSE. It is also often unclear how CDSE and CREODIAS complement each other, and how well individual services and tools comply with open data standards.

A significant obstacle is the reluctance to change existing solutions: systems built on data downloads from the previous Sentinel Data Access Service need to be transitioned to API-based streamlined access on the CDSE. Despite the increase in performance, not all users are willing to commit the resources required for migration.

However, the introduction of CDSE to the market has been successful, evidenced by the appearance of tutorials and use cases created by external users, not just the consortium. All in all, the rapidly growing number of users and followers shows that outreach efforts in 2023 have successfully generated interest in CDSE.

Image Source: *copernicus.eu, Sentinel-3B rocket in the launch tower, copyright ESA - S. Corvaja*

9 DATA ACCESS SYSTEM PERFORMANCE ANALYSIS

Performance analysis has played a key role in the continuous improvement of the CDSE. This section outlines the approach and the results from this continuous analysis process.

Up-to-date system health and performance metrics are available in the Copernicus Dashboard.

9.1. Service availability

Service availability, in general, is defined as the percentage of a given period during which performance is above or below the committed threshold. It consists of two different measurements: Performance Metric for Query (PMQ) and Performance Metric for Immediate Access (PMIA). PMQ measures availability of the interfaces and is continuously checked by a system health-check probe from central monitoring. PMQ is considered unavailable when the average performance drops below the threshold for 5 seconds and is resolved when the average performance is re-established. PMIA measures the download performance via API, with unavailability declared when the download performance drops below 20 MBps. In general, service availability is measured as the availability of system operation at a specific level, rather than periods of total availability or unavailability of the system.

The CDSE availability improved throughout 2023, thanks to continuous optimization efforts aimed at adapting the new system to heavy user traffic. The average availability from May 2023 (when additional services and data were introduced) to the end of 2023 was 98.7%, with availability reaching 99.3% in November-December 2023.

9.2. Network analysis

The incoming traffic comprises systematic ingestion of EO products at the user level, systematic ingestion of AUX and Engineering type EO products (non-user level) initiated in September 2023, and backfilling of S-1 SLC products to CDSE, which began in April and continued until November 2023. A sharp increase occurred in June 2023, which stabilized by September 2023 as most gap-filling activities were completed. Peaks are also linked to the ingestion of reprocessed Sentinel-2 Collection-1 data which were performed with variable speed. Temporally correlated incoming and outgoing traffic is associated with processing activities, such as the S-1 GRD to S-1 GRD COG conversion from May to July 2023, involving both reading and writing data.

In addition to the above-mentioned activities related to the gradual rollout of the CDSE platform in 2023, there has also been an increase in user traffic. Initially the outgoing traffic will have consisted mostly of data transfer related to the CDSE platform phase-in activities, ensuring the completeness of the data collection on the OTC cloud. As the year progresses, CDSE platform activity accounts for less and less of the outgoing traffic, and more and more can be attributed to user activity (Figure 73).

FIGURE 73: The daily outgoing traffic in Gbps in May-December 2023.

9.3. Publication timeliness

Publication timeliness measures the time from when the satellite senses the data to when the data is published on the CDSE. Timeliness depends on the mission's end-to-end design, including the orbit point of image sensing, the geographical position of the receiving antenna, and the priority assigned to each user-level data in the processing and publication chain. Any disturbance in this chain can affect publication timeliness.

User-level data are categorized as Near-Real Time (NRT), Short-Time Critical (STC) or Non-Time Critical (NTC). The expectations for publication timeliness for user-level data are as follows:

- **Sentinel-1:** within 24 hours from sensing.
- **Sentinel-2:** between 3 and 24 hours from sensing.
- **Sentinel-3:** annotated timeliness indicates expected availability:
  - **NRT** less than 3 hours after acquisition
  - **STC** less than 48 hours after acquisition
  - **NTC** 30 days from sensing, allowing consolidation of some auxiliary or ancillary data.
- **Sentinel-5P**
  - **NRT** within 3 hours from sensing
  - **NTC** user-level data, the timeliness threshold depends on the level:
    - Level-1B: within 12 hours from sensing
    - Level-2: within 14 days from sensing.

Mission	Average timeliness for NRT	Increase/ decrease since Y2022*	Average timeliness for NTC	Increase/ decrease since Y2022*	Average timeliness for STC	Increase/ decrease since Y2022*
S1	-		2h 43m	-37m	-	
S2	-		3h 58m	-1h 47m	-	
S3-OLCI	2h 4m	-36m	19h 13m	-2h 47m	-	
S3-SLSTR	2h 2m	-58m	1d 3h 12m	-1h 38m	-	
S3-SRAL	2h 8m	-12m	25d 3h 57m	-1d 9h 0m	1d 15h 55m	+8h 15m
S3-SYNERGY	-		1d 10h 4m	-1h 56m	8h 21m	-1h 59m
S5P-L1B	1h 5m		3h 51m	-1h 9m	-	
S5P-L2	1h 16m	-52m	2d 6h 56m	-3h 4m	-	

TABLE 38: Average publication timeliness over last trimester of 2023 and comparison with last trimester of 2022.
*- compared to data from the 2022 Copernicus Sentinel Data Access Annual Report

Sentinel-1:

Overall, the Sentinel-1 timeliness statistics reflect satisfactory performance, with processing times mostly below 3 hours, except for one month. In April, an anomaly on the PRIP cluster caused publication delays for more than 30,000 Sentinel-1 products (as well as Sentinel-3 products). This delay in publication led to delays in retrieving the products, resulting in an increase in timeliness in April to almost 8 hours, as shown in Table 50 and illustrated in Figure 74. Excluding this one month of delay, the average timeliness was 2 hours and 43 minutes.

Sentinel-1	
Month	**Average publication time [h]**
Mar	2.93
Apr	7.82
May	2.72
Jun	3.32
Jul	2.57
Aug	2.50
Sept	2.55
Oct	2.75
Nov	2.53
Dec	2.85

TABLE 39: Monthly Average Publication Timeliness for Sentinel-1 user-level data during 2023.

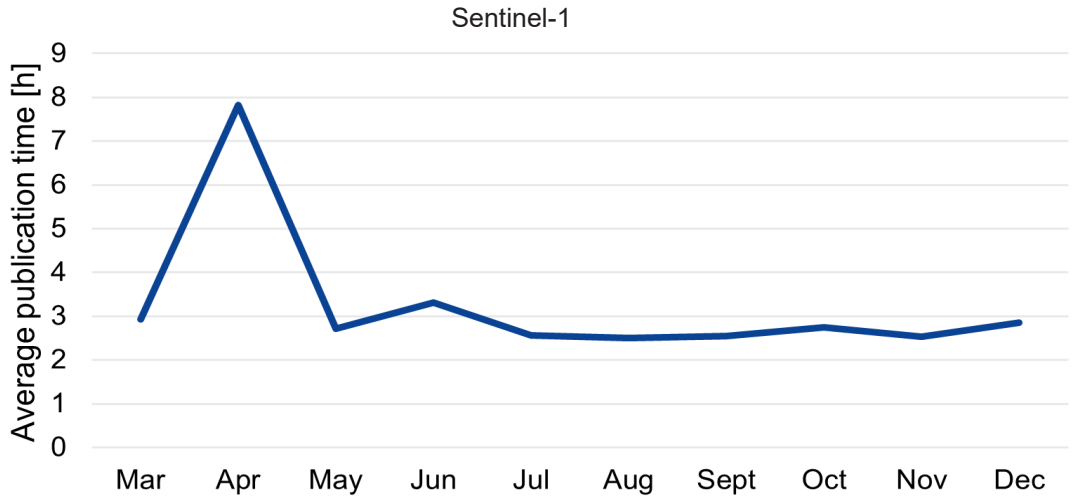


FIGURE 74: Monthly Average Publication Timeliness for Sentinel-1 user-level data during 2023.

Sentinel-2:

Timeliness data for Sentinel-2 products are available starting from October, as this is when CDSE began retrieving data from the PRIP cluster instead of the legacy Sentinel Data Access Service (Copernicus Open Access Hub). In the last three months of 2023, the average timeliness was 4 hours, as shown in Table 40 and illustrated in Figure 75.

Sentinel-2	
Month	**Average publication time [h]**
Oct	4.10
Nov	4.00
Dec	3.88

TABLE 40: Monthly Average Publication Timeliness for Sentinel-2 user-level data during 2023.

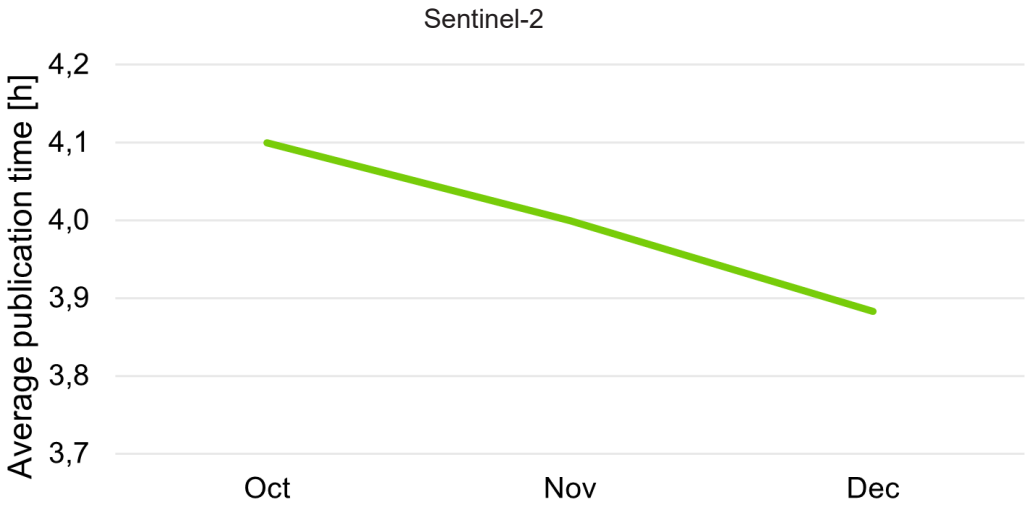


FIGURE 75: Monthly Average Publication Timeliness for Sentinel-2 user-level data during 2023.

Sentinel-3:

Timeliness metrics for Sentinel-3 products generally met expectations. However, in April, an anomaly in the PRIP cluster caused delays in Near-Real Time (NRT) product publication, leading to significantly higher timeliness values, reaching up to 8 hours. This anomaly not only delayed data retrieval but also increased overall timeliness for Sentinel-3. It is important to note that the data do not include products from ongoing reprocessing, as this would affect the timeliness statistics.
Excluding April, the average timeliness for NRT data ranged from 1 hour and 50 minutes for SRAL to 2 hours and 11 minutes for OLCI (Table 41, Figure 76).

For the Non-Time-Critical (NTC) data, the time of publication since acquisition was expected to be longer due to additional processing. There were no significant differences across months, except for April as previously mentioned. The average timeliness was 20 hours for OLCI, 28 hours for SLSTR, 25 days for SRAL, and 35 hours for SYNERGY products (Table 42). Figures 77-78 graphically represent the timeliness time series, with SRAL shown separately due to its different range (days) compared to the rest (hours).

Finally, Table 43 and Figure 79 present the timeliness for Sentinel-3 Short Time Critical (STC) data, with an average of 39 hours for SRAL and 9.5 hours for SYNERGY products.

Sentinel-3 NRT			
Month	Average publication time [h] per instrument		
	OLCI	SLSTR	SRAL
Mar	2.17	2.10	1.97
Apr	7.35	7.08	6.88
May	2.58	2.08	1.97
Jun	2.25	1.93	1.87
Jul	2.33	2.10	1.97
Aug	2.07	1.87	1.75
Sept	2.00	1.87	1.72
Oct	2.10	2.03	1.72
Nov	2.25	2.22	1.93
Dec	1.87	1.85	1.62

TABLE 41: Monthly Average Publication Timeliness for Sentinel-3 NRT user-level data during 2023.

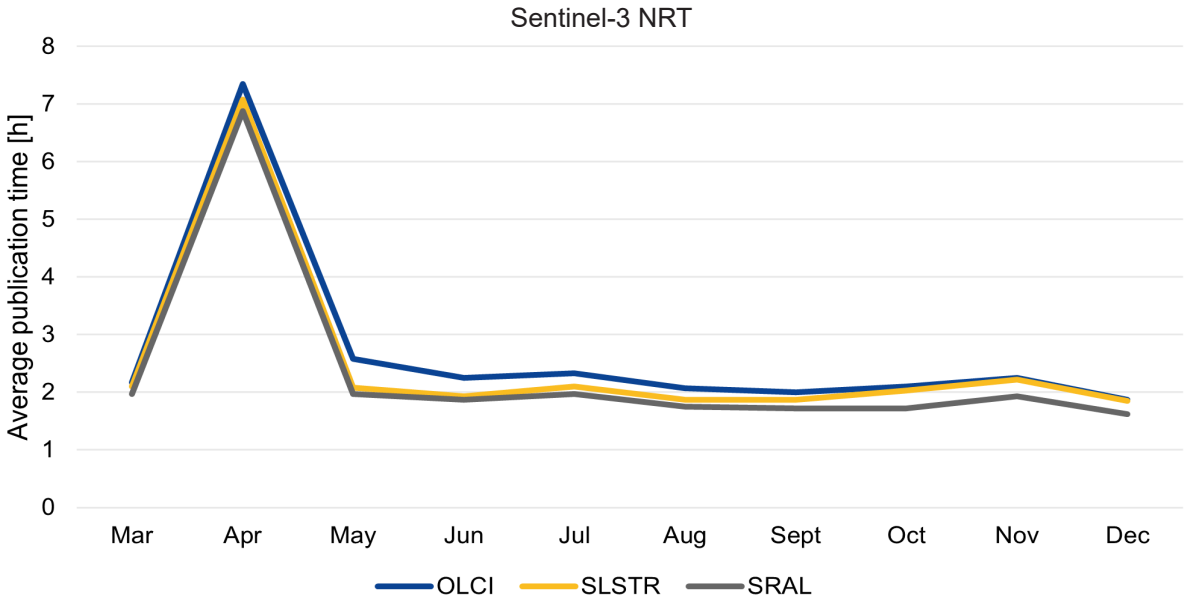


FIGURE 76: Monthly Average Publication Timeliness for Sentinel-3 NRT user-level data during 2023.

Sentinel-3 NTC				
Month	Average publication time [h] per instrument			
	OLCI	SLSTR	SRAL	SYNERGY
Mar	20.05	27.83	605.08	36.10
Apr	24.77	32.30	608.02	40.35
May	20.15	27.53	603.03	35.93
Jun	20.10	27.08	602.78	35.80
Jul	19.97	27.38	603.13	36.32
Aug	19.22	26.73	602.70	34.75
Sept	19.15	26.98	602.80	34.27
Oct	19.22	27.30	602.45	34.35
Nov	19.45	27.30	602.67	34.15
Dec	19.02	27.03	602.25	33.72

TABLE 42: Monthly Average Publication Timeliness for Sentinel-3 NTC user-level data during 2023.

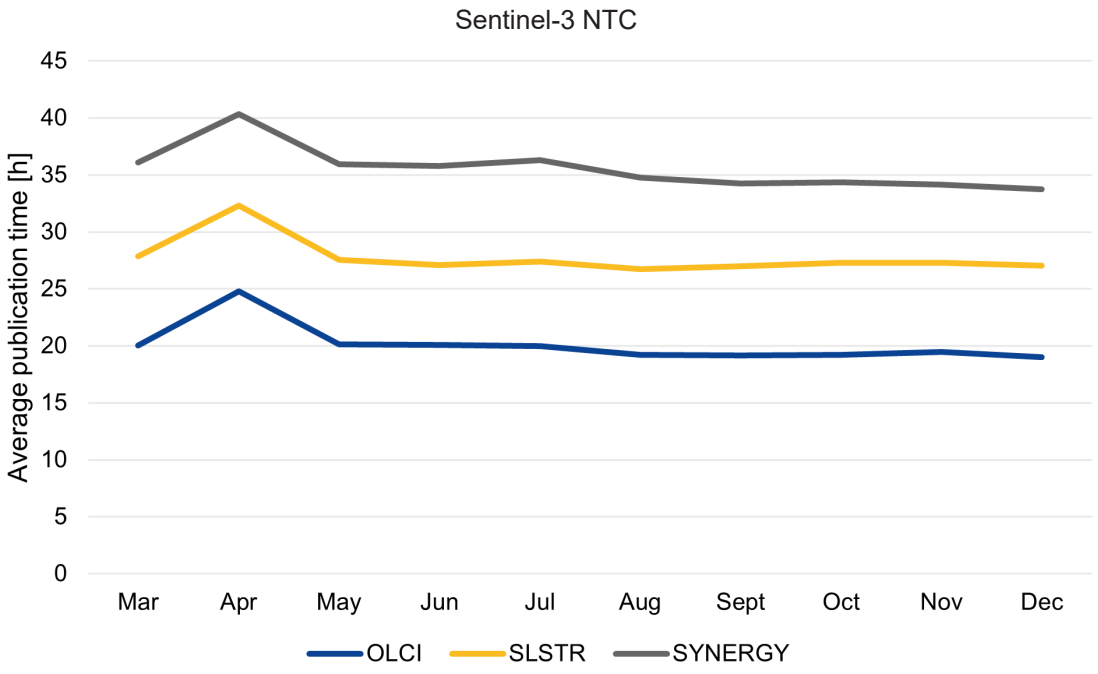


FIGURE 77: Monthly Average Publication Timeliness for Sentinel-3 NTC (OLCI, SLSTR, SYNERGY) user-level data during 2023.

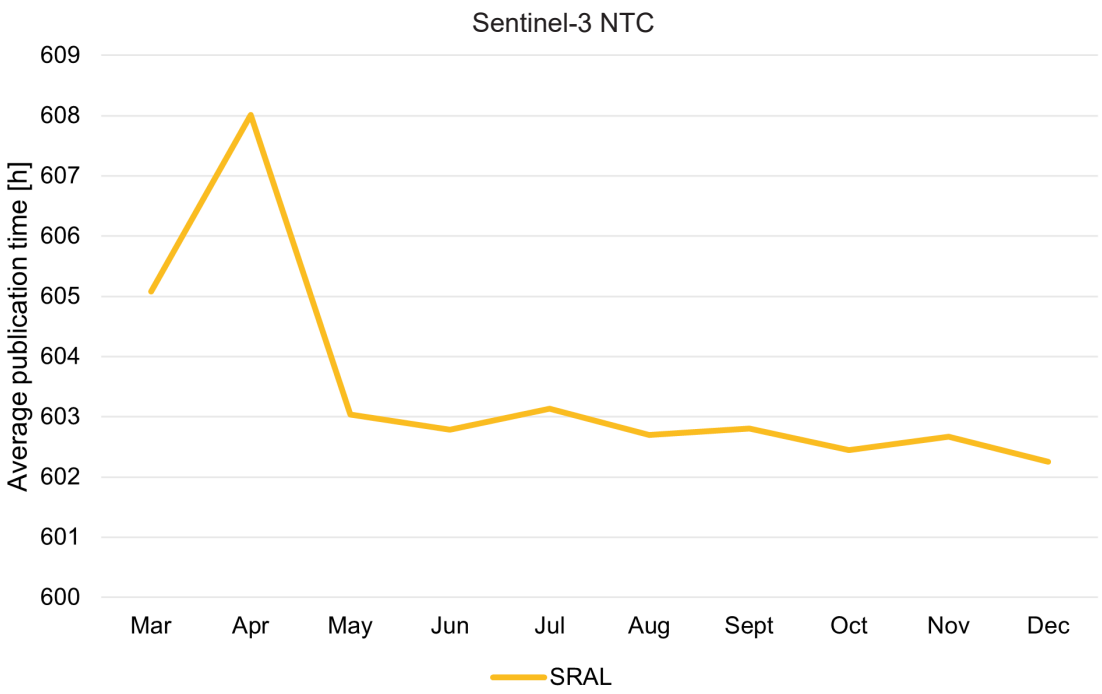


FIGURE 78: Monthly Average Publication Timeliness for Sentinel-3 NTC (SRAL) user-level data during 2023.

Month	Sentinel-3 STC Average publication time [h] per instrument	
	SRAL	SYNERGY
Mar	38.15	9.72
Apr	43.08	14.20
May	40.90	9.65
Jun	37.82	9.72
Jul	38.07	10.00
Aug	37.72	8.63
Sept	37.77	8.50
Oct	38.28	8.53
Nov	38.47	8.53
Dec	38.10	8.00

TABLE 43: Monthly Average Publication Timeliness for Sentinel-3 STC (SRAL) user-level data during 2023.

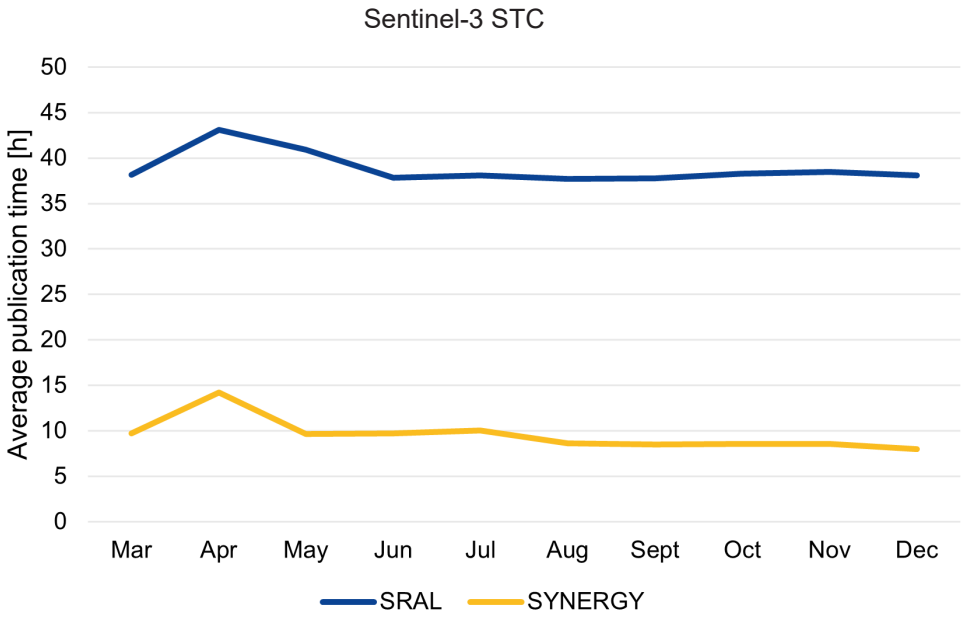


FIGURE 79: Monthly Average Publication Timeliness for Sentinel-3 STC user-level data during 2023.

Image source: *esa.int, Dorian brings destruction, modified Copernicus Sentinel data, ESA standard licence*

Sentinel-5P:

From July onwards, the timeliness statistics for each month met expectations, consistently reflecting satisfactory performance. June, was an exceptional month where the values were notably higher than usual due to the initiation of Sentinel-5P data retrieval, which began in the middle of the month. Following the switch to Sentinel-5P PRIP, ingestion and retrieval of historical data were performed, along with retrieving missing data from the previous seven days. These events collectively contributed to exceptionally high timeliness for June.

On average, excluding June, NRT L1B data was published 1 hour and 15 minutes after sensing, and NRT L2 data after 1 hour and 25 minutes (Table 44 and Figure 80).

Sentinel-5P NRT		
Month	Average publication time [h] per instrument	
	L1B	L2
Jun	48.02	8.08
Jul	1.20	1.32
Aug	1.45	1.57
Sept	1.65	1.82
Oct	1.25	1.43
Nov	1.00	1.20
Dec	0.98	1.17

TABLE 44: Monthly Average Publication Timeliness for Sentinel-5P NRT user-level data during 2023.

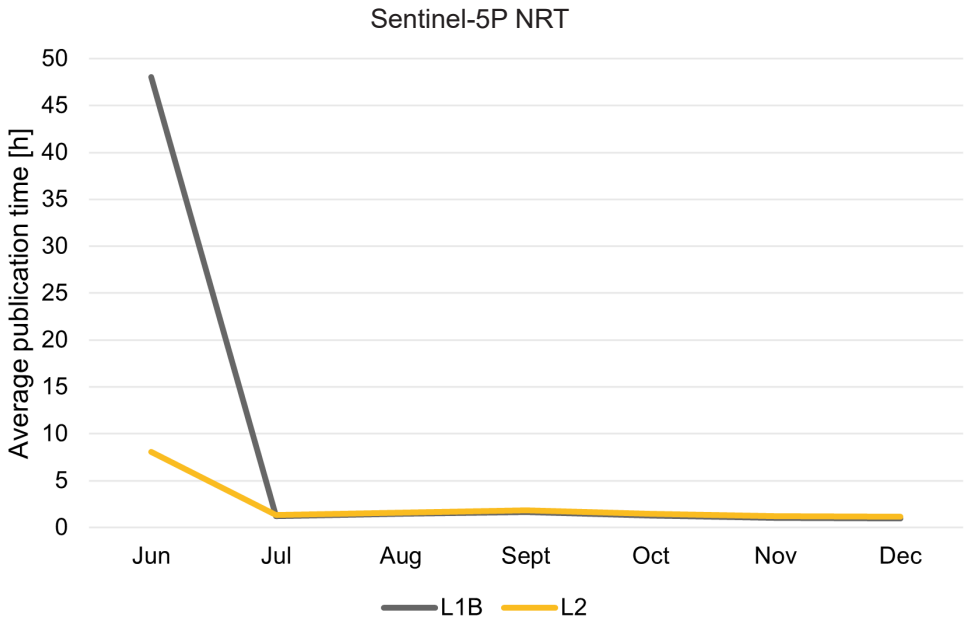


FIGURE 80: Monthly Average Publication Timeliness for Sentinel-5P NRT user-level data during 2023.

Regarding Non-Time-Critical (NTC) data, across almost all months, the Sentinel-5P NTC timeliness met anticipated standards, consistently demonstrating proper performance levels. However, in one month, September, the threshold value for Level-1B was surpassed due to an anomaly. During the first two weeks of September, the metadata of certain Sentinel-5P NTC products were empty, making those products unavailable for retrieval from PRIP. After the metadata issue was addressed and fixed, retrieval became possible but the anomaly resulted in significantly reduced average timeliness for the Sentinel-5P products in September.

Excluding the anomalous September, the average timeliness for 2023 was below 5 hours for L1B NTC, and 65 hours for L2 NTC (Table 45 and Figure 81).

Sentinel-5P NTC		
Month	Average publication time [h] per instrument	
	L1B	L2
Jun	3.78	57.52
Jul	5.83	60.45
Aug	7.38	54.72
Sept	47.45	96.47
Oct	3.82	53.03
Nov	4.05	58.53
Dec	3.68	53.55

TABLE 45: Monthly Average Publication Timeliness for Sentinel-5P NTC user-level data during 2023.

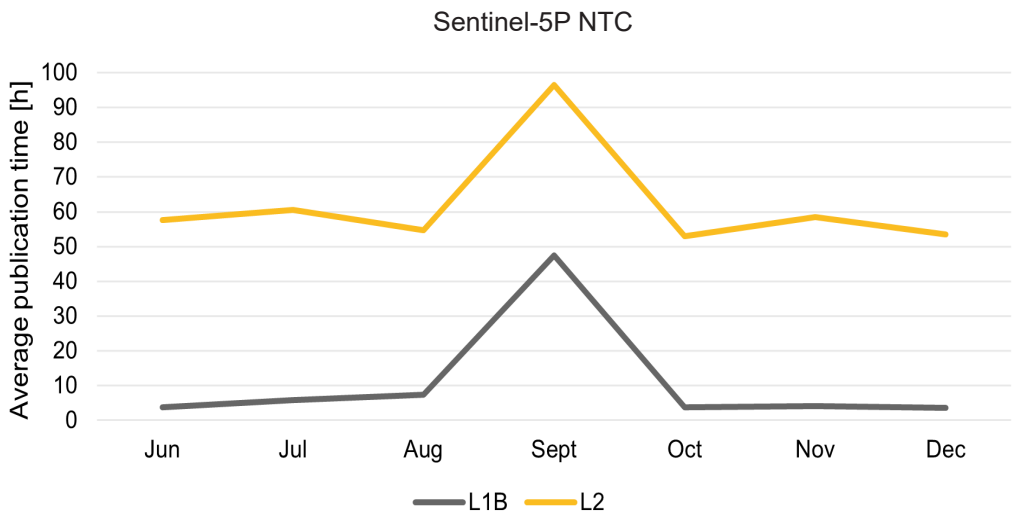


FIGURE 81: Monthly Average Publication Timeliness for Sentinel-5P NTC user-level data during 2023.

10 END-USER SUPPORT AND FEEDBACK

User feedback is continuously monitored to ensure our data access service meets expectations and to quickly address any issues. Users can easily reach the user support help center via the CDSE web portal (https://helpcenter.dataspace.copernicus.eu/hc/en-gb) and are encouraged to contact support using ‚Submit a request'. This support is available to users of all expertise levels in the EO industry, public administration, and academic community.

We have established five pillars of support for our users. By the end of the year, we evaluated all user experiences based on the feedback received.

10.1. The five pillars of the CDSE user support

The CDSE user support is based on five pillars: the FAQ collection, the documentation portal, the user helpdesk, community forum, and video tutorials (Figure 82).

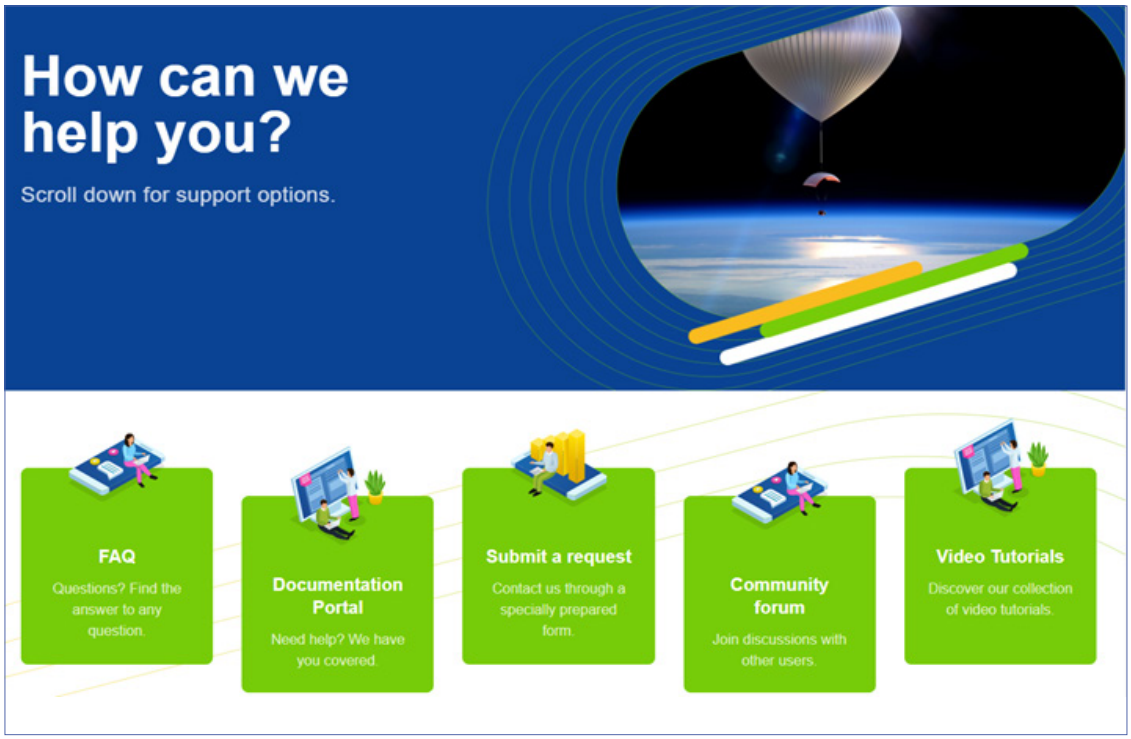


FIGURE 82: The five-pillar structure of the user support.

FAQ

The FAQ section continually gathers the most common problems, questions, and use cases. While there is already a substantial collection available, it is continuously evolving. The FAQ page is designed to provide quick answers to common questions and queries.

Documentation portal

CDSE offers extensive documentation that provides end-users with insights into the comprehensive Earth Observation data collection and the various data access and processing capabilities. The documentation is a dynamic resource, continuously updated to provide the latest information.

Main sections of the documentation:

- Data: Users can explore large amounts of open and free Earth Observation datasets, including Sentinel Data, Copernicus Contributing Missions, Federated Datasets, and Complementary Data, with detailed information.
- APIs: Users can find the perfect interface for their needs in our suite of APIs. Whether they seek catalogue access, product downloads, data visualization, or processing capabilities, our offerings encompass a range of options, including S3, STAC, openEO, and Sentinel Hub APIs.
- Applications: User can learn how to simplify their satellite data journey and engage with data using our user-friendly applications for searching, visualizing, modifying, and downloading data effortlessly.
- Quotas and Limitations: Users can get to know the quotas and limitations that come with their user type and plan their data download and processing pipelines accordingly.

If users have any questions that remain unanswered on this portal, they are always encouraged to contact the CDSE Support team (https://documentation.dataspace.copernicus.eu/Support.html), who is ready to assist anytime.

The user helpdesk

Helpdesk is responsible for end-user support, including the follow-up of any requests logged by end-users using the Copernicus Data Space Ecosystem. The objective of the helpdesk service is to ensure a positive end-user experience in request follow up.

Submitting a request

Users who have not registered and have general questions can submit their inquiries using the webform on the About Copernicus Data Space Ecosystem page (https://dataspace.copernicus.eu/about).
For technical queries, users are required to register and submit a request through the User Support Help Center (https://helpcenter.dataspace.copernicus.eu/hc/en-gb).
The dedicated request form allows users to specify the nature of their query (e.g., data offerings, analysis tools, APIs, etc.). The user Support Help Center also enables users to track their submitted requests directly through their account, as well as follow the related email conversation (support@dataspace.copernicus.eu).

Communities around the CDSE

With the increase in registered users, there is a great opportunity for flourishing user communities. CDSE is proud of the existing EO communities and envisions significant growth in the coming years. To support this, CDSE is continuously improving the forum environment (https://forum.dataspace.copernicus.eu) according to the user needs, creating a user-friendly space where end-users can share their experiences with others. Building a top-notch user forum community is a key objective for CDSE.

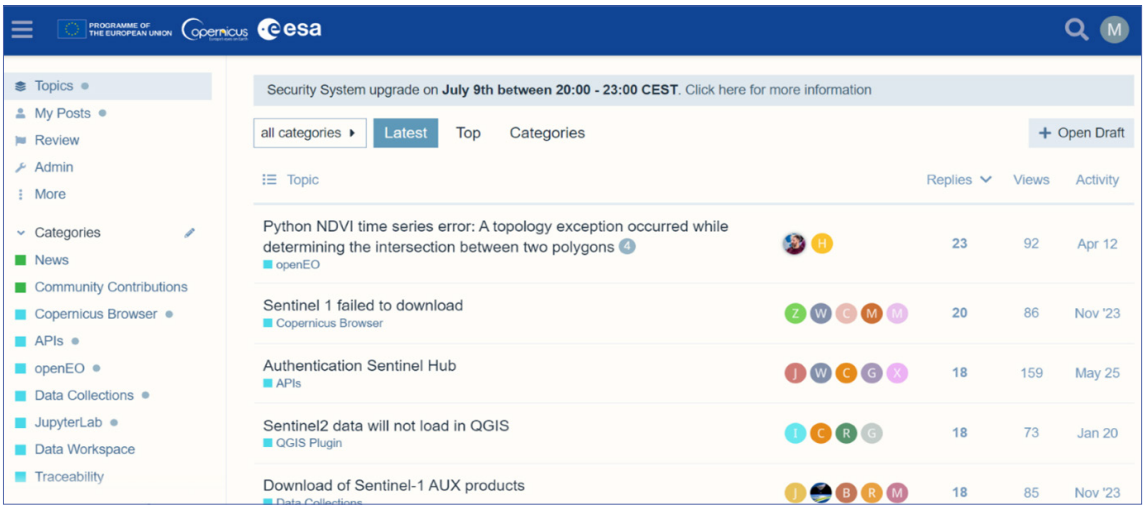


FIGURE 83: CDSE Forum environment.

Video tutorials

The Copernicus Data Space Ecosystem offers several videos about features, tutorials and highlights that demonstrate the use of the Ecosystem. These videos (https://dataspace.copernicus.eu/videos) cater to both EO professionals building scientific or business solutions and members of the public interested in remote sensing. User can access several introductory videos directly via CDSE or via the YouTube channel. The video section is constantly extended based on user feedback and requests.

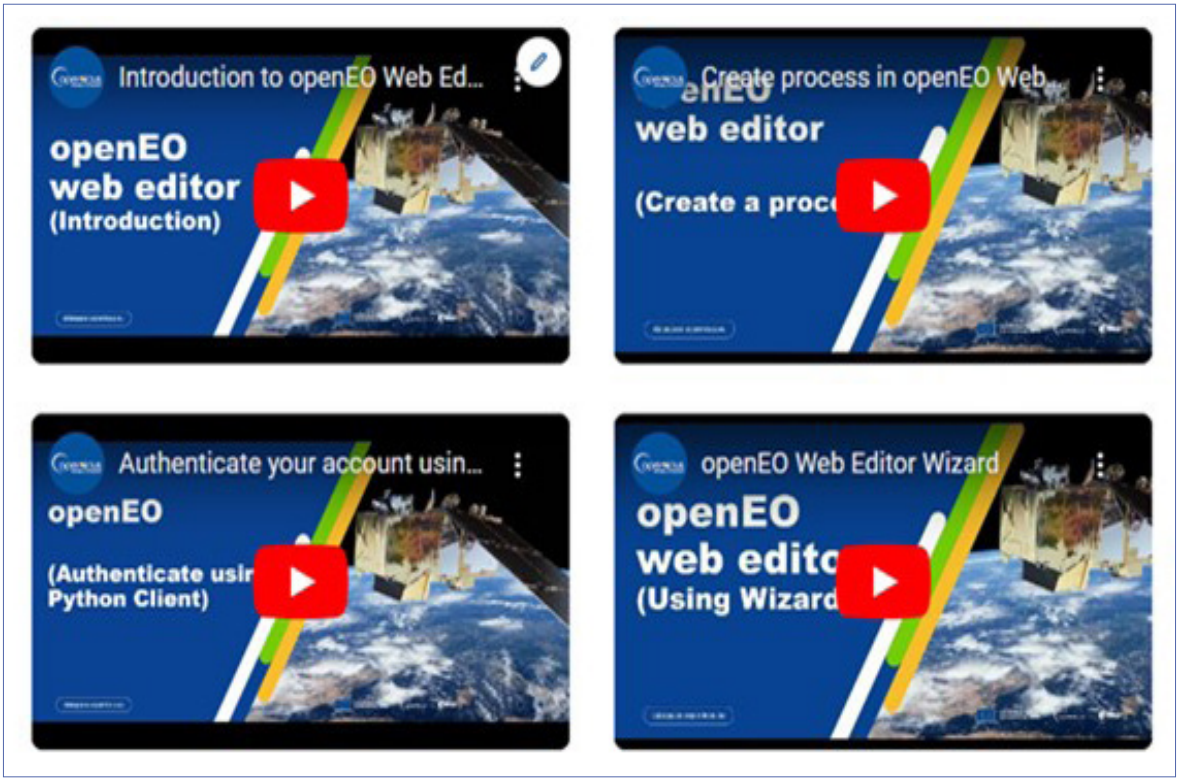


FIGURE 84: Example of video tutorials on CDSE website.

10.2. News Management

The CDSE consortium keeps the News section of the website (https://dataspace.copernicus.eu/news) up to date with essential operational information and promotions. This page provides the latest news from the ecosystem, ensuring all users are informed about the necessary operational details.

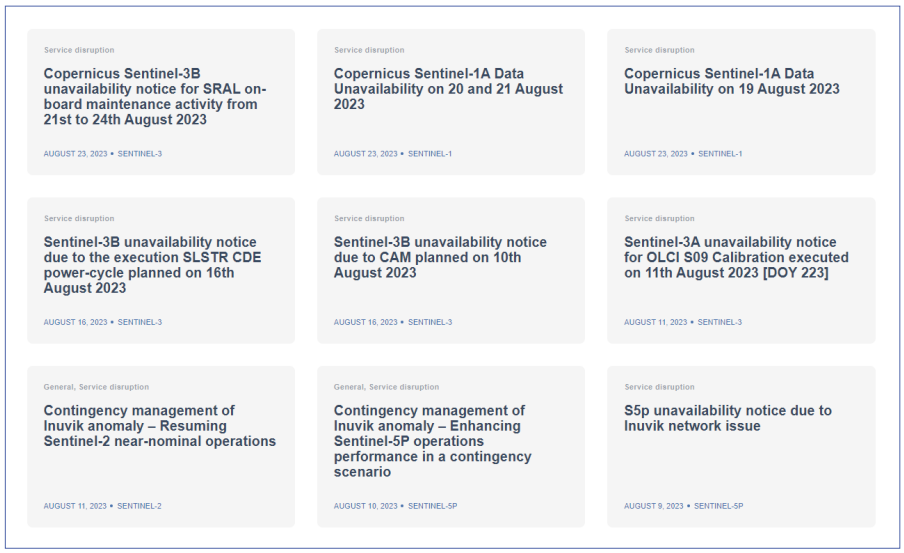


FIGURE 85: CDSE News page.

10.3. User satisfaction

The operational phase of CDSE began in July 2023, and we are now reflecting the user satisfaction score based on the number of tickets received by the service desk since the launch.

CDSE has implemented a satisfaction rating system within the helpdesk to better evaluate ongoing services and understand user needs, with the goal of continuous service improvement.

Users are asked to rate the service by expressing their satisfaction once their ticket is resolved.

Figure 86 shows a peak of tickets being opened in October to November 2023, and it is assumed this is linked to the high numbers of new users registering on the CDSE in those months.

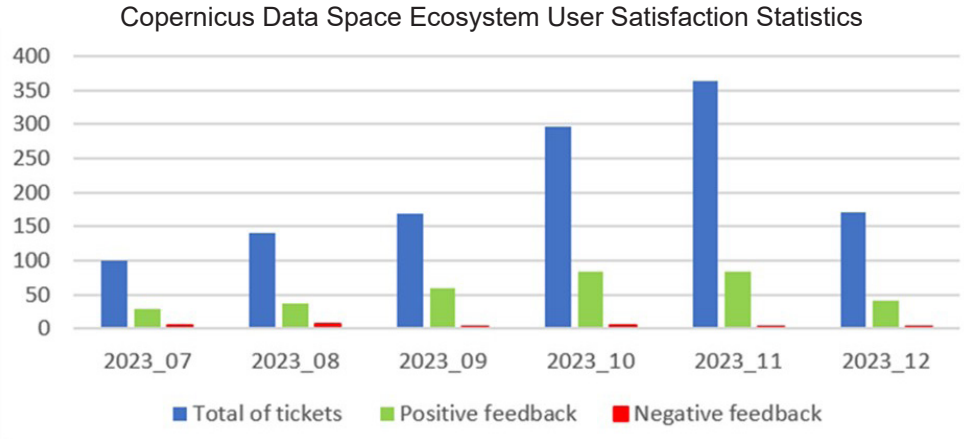


FIGURE 86: The total number of tickets received by support (blue), with positive ratings (green) and negative ratings (red).

Ticketing analysis

In the second half of 2023 (July-December), we received a total of 1,241 tickets. Of these, 99.35% were resolved within the contractually obligated resolution time of 5 normal working days. The average resolution time for all tickets was 11 hours and 10 minutes. Only 8 tickets required a longer resolution time, due to their complexity.

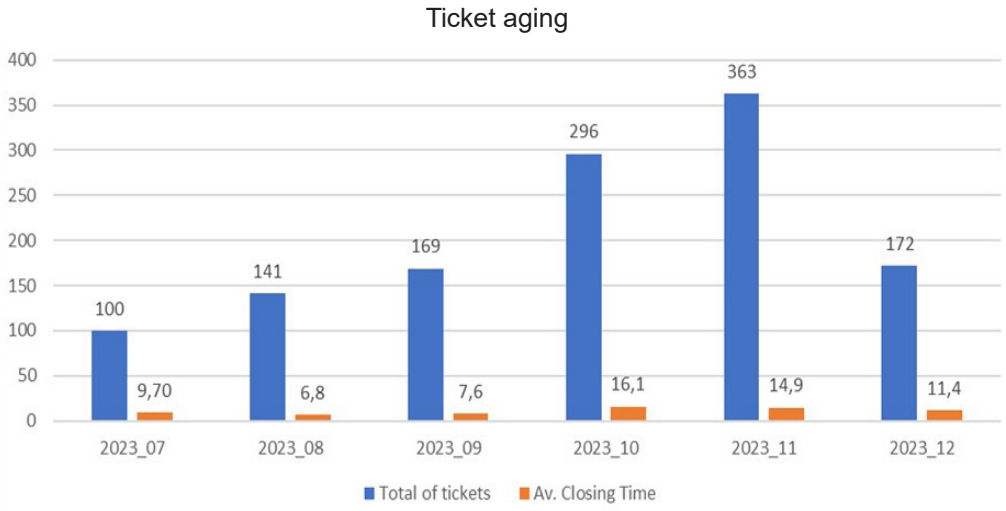


FIGURE 87: Ticket aging statistics demonstrating total of ticket received per month and average closing time (hrs).

Service Catalogue

The Service Catalogue is maintained in the user support system using categories to allow effective categorization of reported issues. Requests from CDSE users are tracked via a ticketing system, with open tickets sorted into five main categories and 18 subcategories:

Data Offering
- Copernicus and Sentinel Data
- On Demand and Commercial Data
- Copernicus Contribution Missions
- Federated Data Sets

Analysis Tools
- Copernicus Browser
- Marketplace
- JupyterLab
- Data workspace and On-Demand processing
- openEO
- Dashboard
- Traceability service

API's
- Catalogue and download API's
- openEO
- Sentinel Hub
- Traceability
- On demand production

Ecosystem
- Commercial services
- Public services

Other

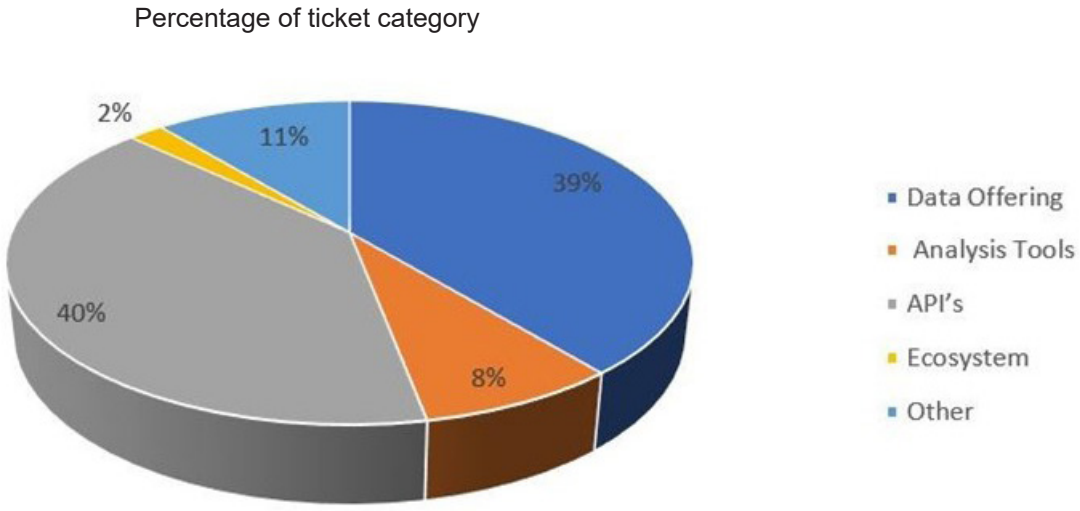


FIGURE 88: Percentage of each category of tickets received.

The largest proportion of tickets were for APIs (40%), mainly Catalogue and Download APIs; followed by Data Offering (39%): majority Copernicus and Sentinel Data; Analysis Tools (8%): Browser and General tickets; and the rest were for 'Ecosystem' and 'Other' (13%).

10.4. Outlook and plan for service desk improvements in 2024

The CDSE consortium organized its first **User Review Meeting** on **April 15, 2024**, both, onsite in Vienna and online. This hybrid event aimed to enhance the CDSE through valuable user insights. The User Review Meeting was crucial for shaping the future, fostering innovation, and meeting the evolving needs of the users.

Prior to the event, a **User Review Survey** was distributed among the user groups, and the results were analysed and presented at the meeting.

In 2024, the **Forum environment** will be improved to engage a larger portion of the community on a more user- friendly platform.

Additionally, a call for **use cases** will be launched and collected, to expand knowledge across the Earth Observation community.

11 SUSTAINABILITY

It is a key priority for the European Commission (EC) to reduce its greenhouse gas (GHG) emissions by 46% by 2030 compared with 2019 levels, and generally decrease the environmental impacts of its programs and activities. Hence, the European Space Agency (ESA), an intergovernmental organization closely cooperating with the EC, seeks to be proactive in the way it measures the environmental sustainability of its products and services and derive further measures to reduce their environmental impacts. Carbon footprint calculations represent one of these measuring methods.

As a European institution, ESA takes into consideration the needs of future generations, with respect to the environment, economy, and society (the three “sustainability pillars”).

On this basis, the adoption of the ISO 26000 guidelines led to the integration of various CSR principles (see Figure 58 below) into ESA’s organizational structure, programmes, and activities, thereby reinforcing its overall contribution to the sustainable development of society and a responsible space sector. Furthermore, ESA has developed a wide range of measures and programmes seeking to help achieve the Sustainable Development Goals.

Considering the environment, ESA continuously works towards becoming more responsible and sustainable. The “ESA Agenda 2025” was adopted in 2021 and defines the priorities as well as the vision until the year 2025. This agenda made it clear that ESA seeks to strongly contribute to the carbon neutrality of Europe. The political objectives set out in the Paris Agreement and the European Green Deal were specifically integrated into the ESA Agenda 2025.

11.1. Measuring scope and methodology

The monitoring and reporting of the carbon footprint both require its calculation and the measurability of the improvement measures of the footprint. The calculation is governed and performed by T-Systems, ensuring the same methodology is used by the two public cloud systems supporting the CDSE infrastructure, Open Telekom cloud (OTC) and the CloudFerro cloud.

The calculation focuses on:

- Scope 1 emissions (i.e., GHG emissions which result directly from within both companies – T-Systems and Cloud Ferro)
- Scope 2 emissions (i.e., indirectly caused from the use of purchased energy).

For this purpose, the energy consumption, input and output energy data of the hardware (servers, switches, routers) used for CDSE were collected from the data centres of the OTC and CloudFerro clouds.

11.2. CONCLUSION

- The results of the carbon footprint of the T-Systems OTC cloud and CloudFerro cloud components relevant to the CDSE show strengths of the respective providers' sustainability activities.
- On a positive note, the data centres used by T-Systems and CloudFerro use 100% renewable energy and are already very efficient. The PUE (Power Usage Effectiveness) value is in the target range between 1 and 1.5.
- Even if the PUE values are already good, further improvement towards a PUE value of close to 1 can be strived for in the future.
  - The T-Systems OTC cloud data centres require 30% less energy than comparable data centres. The Power Usage Effectiveness (PUE) value is between 1.40 and 1.46.
  - The PUE of the CloudFerro data centres are slightly above the target value of 1.5 and range from 1.58 to 1.65.
  - When comparing the sustainability metrics and goals of other cloud service providers, T Systems performs well in terms of renewable energy share. The results show that OTC's hardware have an overall energy consumption of 73,83 MWh/year due to the CDSE service operations, while the hardware components of CloudFerro result in an approximate energy consumption of 103,74 MWh/year.
  - Due to the prevailing condition that no CO_2 emissions are caused by using renewable energies, the CO2 emission for these consumption values is zero.
  - In terms of cooling efficiency, an already efficient cooling technology is in use in a T-System data centres. However, to be able to prove future improvement in this regard, it is recommended to measure the CER KPIs going forward.

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A Annex 1: Special Terms and Definition

Name	Definition
ArcGIS	ArcGIS is a family of client software, server software, and online geographic information system services developed and maintained by Esri. ArcGIS was first released in 1999 and originally was released as ARC/INFO, a command-line based GIS system for manipulating data.
CDSE	Copernicus Data Space Ecosystem. An open ecosystem that provides free instant access to a wide range of data and services from the Copernicus Sentinel missions and more on our planet's land, oceans, and atmosphere.
CREODIAS	The brand of the commercial service platform, that has been implemented in 2015, advanced to a Copernicus DIAS service in 2018 and since then has become the leading cloud-service platform for the user communities. It will provide the core platform for the new Copernicus Data Space services and the brand will be continued for the commercial services of the Copernicus Data Space, whereas the free and open services contracted by ESA will be provided through the linked Open Data Space.
EARSC	The European Association of Remote Sensing Companies is a membership-based, not for profit organization which coordinates and promotes the activities of European companies engaged in delivering Earth observation-derived geo-information services. EARSC represents this sector in its broadest sense, creating a network between industry, decision makers and users and covering the full EO value chain from data acquisition through processing, fusion, analysis to final geo-information products & services.
Euro Data Cube	Euro Data Cube is a partnership between industry leading companies, working together to reduce the gap between data and knowledge, led by Sinergise and supported by ESA. It provides immediate access to analysis-ready data, various applications and tools for exploitation and a marketplace for third parties to foster collaboration. Users have access to free and commercial services with a public price list. Euro Data Cube also supports the ESA Rapid Action on COVID-19 program (RACE).
Gaia-X	Gaia-X is an initiative that develops a software framework of control and governance and implements a common set of policies and rules that can be applied to any existing cloud/ edge technology stack to obtain transparency, controllability, portability and interoperability across data and services. The framework is meant to be deployed on top of any existing cloud platform that decides to adhere to the Gaia-X standard. Gaia-X is not a market operator, nor will it operate directly or exclusively any of the services required by the framework. Gaia-X services will be created, operated, and adopted by the market through operators deciding to adopt the Gaia-X standard.
GeoServer	GeoServer is an open-source server written in Java that allows users to share, process and edit geospatial data. Designed for interoperability, it publishes data from any major spatial data source using open standards.
IDS	The International Data Spaces Association (IDSA) is on a mission to create the future of the global, digital economy with International Data Spaces (IDS), a secure, sovereign system of data sharing in which all participants can realize the full value of their data.
Open Data Space (Portal)	The Open Data Space is the portal proposed to provide a neutral and free entry to the CSC Data Access Services in the Data Space provided by the Consortium. It could replace the Copernicus Open Access Hub and other portals currently providing the Data Access and e.g., continue the Copernicus branding and domain names.

Name	Definition
openEO	openEO is an H2020 project funded under call EO-2-2017: EO Big Data Shift, under grant number 776242. The project ran from Oct 2017 to Sept 2020. openEO developed an open API to connect R, Python, JavaScript, and other clients to big Earth observation cloud back-ends in a simple and unified way.
Open Telekom Cloud	The leading public cloud service in Europe based on the Open-Source Cloud Computing Infrastructure OpenStack. Open Telekom Cloud was launched in 2015 and meanwhile manages more than 500 Petabyte of customer data. Since 2018, Open Telekom Cloud provides the infrastructure and services for the Copernicus DIAS Mundi Web Services. Open Telekom Cloud is owned by Deutsche Telekom AG and operated by its 100% subsidiary T-Systems, in multiple data centres spread over two regions around Amsterdam (Netherlands) and Magdeburg (Germany).
QGIS	QGIS is a free and open-source cross-platform desktop geographic information system application that supports viewing, editing, and analysis of geospatial data.
Sentinel Hub	Sentinel Hub is an engine for processing of petabytes of satellite data. It is opening the doors for machine learning and helping hundreds of application developers worldwide. It makes Sentinel, Landsat, and other Earth observation imagery easily accessible for browsing, visualization and analysis. Scale your system globally with an intuitive and user-friendly interface, without any hassle.
STAC (Catalogue)	The Spatio-Temporal Asset Catalogue (STAC) specification provides a common language to describe a range of geospatial information, so it can more easily be indexed and discovered. A 'spatiotemporal asset' is any file that represents information about the earth captured in a certain space and time.
Swagger	Swagger is an Interface Description Language for describing RESTful APIs expressed using JSON. Swagger is used together with a set of open-source software tools to design, build, document, and use RESTful web services. Swagger includes automated documentation, code generation, and test-case generation.
Terrascope	Terrascope is the Belgian Collaborative Ground Segment hosting a multitude of cutting-edge services on top of Copernicus-based added value datasets. The platform is developed, hosted, and maintained by VITO.
WEkEO	WEkEO is the EU Copernicus DIAS reference service for environmental data, virtual processing environments and skilled user support. A platform operated by EUMETSAT.
Zendesk	Zendesk is the name of a company that provides software-as-a-service products related to customer support, sales, and other customer communications under the Zendesk brand.

B Annex 2: Abbreviation and Definition

Abbreviation	Definition
AARC	Authentication and Authorisation for Research and Collaboration
AER	Archive Exploitation Ratio
API	Application Programming Interface
AOI	Area Of Interest
B2B2x	Business-to-Business (relation) that may also include the end-user (relations)
B2C	Business-to-Consumer (relation)
BCP	Baseline Price Component
BOC	Beginning of Contract
BIPR	Background Intellectual Property Rights
BM	Bare Metal (server)
CCM	Copernicus Contributing Missions / Complementary Missions
CDAS	Copernicus Data Access Services
CDSE	Copernicus Data Space Ecosystem
CDSA	Copernicus Data Space Attractiveness
CF	CloudFerro
CLS	Collect Localization Satellites
CMEMS	Copernicus Marine Environment Monitoring Service
CoIHub	Collaborative Hub
CoIIGS	Collaborative Ground Segment
CPU	Central Processing Unit
CSC	Copernicus Space Component
CSV	Comma Separated Values
DAD	Deferred Access Data / Deferred Available Data
DAPS	Dynamic Attributes Provisioning Service
DAT	Dynamic Attribute Tokens
DDoS	Distributed Denial of Service
DEM	Digital Elevation Model
DHR	Data Hub Relay
DHuS	Data Hub Software
DFT	Default timeliness
DIAS	Data and Information Access Services
DIL	Deliverable Items List
DLR	German Aerospace Center (Deutsches Zentrum für Luft und Raumfahrt)
DR	Disaster Recovery
DWDM	Dense Wavelength Division Multiplex
EARSC	European Association of Remote Sensing Companies
EC	European Commission
ECSS	European Cooperation on Space Standardization (ECSS standard)
EDRS	European Data Relay System

Abbreviation	Definition
EO	Earth Observation
EOSC	European Open Science Cloud
ESA	European Space Agency
ESRIN	European Space Research Institute
EU	European Union
GA	Geoscience Australia
GDPR	European General Data Protection Regulation
GIS	Geographic Information System
GML	Geography Markup Language
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GRD(H/M)	Ground Range Detected (High/Medium Resolution)
GRNET	Greek Research and Technology Network
GS	Ground Segment
GUI	Graphical User Interface
HA	High availability
HDD	Hard Disk Drive
HLOP	High Level Operations Plan
HSQL	HyperSQL (Database)
HTTP	Hypertext Transfer Protocol
IaaS	Infrastructure as a Service
IAD	Immediate Access Data / Immediate Available Data
IAM	Identity and Access Management
ICT	Information and Communication Technology
IDPS	Intrusion Detection and Prevention System
IDS-RAM	International Data Space Reference Architecture Model
IntHub	International Hub
IOCR	In Orbit Commissioning Review
IPF	Instrument Processing Facility
IPR	Intellectual Property Rights
ISRO	Indian Space Research Organization
ITIL	IT Infrastructure Library
ITSM	IT Service Management
ITT	Invitation to Tender
KPI	Key Performance Indicator
LEO	Low Earth Orbit
LRM	Low Resolution Mode
LTA	Long Term Archive
MET-NO	Norwegian Meteorological Institute
ML	Machine Learning
MSI	Multispectral Instrument (Sentinel-2 instrument)

Abbreviation	Definition
MTU	Maximum Transmission Unit
MTBF	Mean Time Between Failure
MTTR	Mean Time To Repair
NASA	National Aeronautics and Space Administration
NOA	National Observatory of Athens
NOAA	National Oceanic and Atmospheric Administration
NRT	Near-Real Time
NTC	Non-Time-Critical
NWD	Normal Working Days
NWH	Normal Working Hours
OCN	Ocean (S-1 user-level data category)
OCP	Optical Communications Payload (for EDRS)
OData	Open Data Protocol
OBS	Object-based Storage
OCRE	Open Clouds for Research Environments
ODS	Open Data Space
ODP	On-Demand Production
OFFL	Offline
OGC	Open Geospatial Consortium
OLCI	Ocean and Land Color Instrument (Sentinel-3 instrument)
Open Hub	Copernicus Open Access Hub
OSF	Open-Source Framework
OSS	Open-Source Software
OTC	Open Telekom Cloud
OTS	Off the shelf
PAC	Processing and Archiving Centre
PaaS	Platform as a Service
PDS	Professional Data Space (using the CreoDIAS brand)
PDGS	Payload Data Ground Segment
PI-TDO	Performance Indicator to measure the trend in data sets offer in the Copernicus Data Space
PI-TSO	Performance Indicator to measure the trend in services offer in the Copernicus Data Space
PI-TSE	Performance Indicator to measure the trend in service event organised to foster growth of the Copernicus Data Space
PI-TUO	Performance Indicator to measure the trend in users onboarded in the Copernicus Data Space
PMBOK®	Project Management Body of Knowledge
PMI	Project Management Institute
PLRM	pseudo-LRM
POD	Precise Orbit Determination
PoP	Point-Of-Presence
PRIP	Production Interface delivery Points
PuP	PARC Universal Packet

Abbreviation	Definition
SaaS	Software as a Service
SIEM	Security Incident and Event Monitoring
SIN	Sinergise
SMP	Service Management Plan
QA	Quality assurance
R&D	Research and Development
RAID	Redundant Array of Independent Disks
RAM	Random-access memory
REST, RESTful	Representational state transfer (internet protocol)
RINEX	Receiver Independent Exchange Format
S3	Interface to operate Object Storage
S-1	Sentinel-1
S-2	Sentinel-2
S-3	Sentinel-3
S-5P	Sentinel-5 Precursor
SAFE	Standard Archive Format for Europe
SAR	Synthetic Aperture Radar
SARA	Sentinel Australasia Regional Access
ServHub	Copernicus Services Hub
SIEM	Security Information and Event Manager
SLA	Service Level Agreement
SLC	Single Look Complex
SLSTR	Sea and Land Surface Temperature Radiometer (Sentinel-3 instrument)
SME	Small and Medium Enterprise
SMOS	Soil Moisture and Ocean Salinity satellite
SOC	Security Operations Centre
SPOC	Single Point of Contact
SRAL	SAR Altimeter (Sentinel-3 instrument)
SSAU	State Space Agency of Ukraine
SSI	Self-Sovereign Identity
STAC	Spatio-Temporal Asset Catalogues
STC	Short Time Critical
STFC	Science and Technology Facilities Council
SYN	Synergy (Sentinel-3 user-level data type group)
TCI	True Color Image
TEC	Total Electron Content
TOA	Top Of Atmosphere
TROPOMI	TROPOspheric Monitoring Instrument (Sentinel-5P)
TSY / TSI	T-Systems
TT	Trouble Ticket
URL	Uniform Resource Locator

Abbreviation	Definition
USGS	United States Geological Survey
UTC	Coordinated Universal Time
VC	Verifiable Credentials
VLAN	Virtual Local Area Network
VM	Virtual Machine
WAN	Wide Area Network
WBS	Work Breakdown Structure
WCS	Web Coverage Service
WFS	Web Feature Service
WMS	Web Map Service
WMTS	Web Mapping Tiling Service
XML	Extensible Markup Language
ZAMG	Zentralanstalt für Meteorologie und Geodynamik

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